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The ZWERG Project: a Platform for Innovative Logging Tools

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ABSTRACT

Analyzing the needs of logging tools leads to the discovery that a lot of equipment, concepts and engineering details are similar, no matter of the probes respective service function. The logging truck, the control cabinet, the winch, the wireline cable and the cablehead follow a couple of quasi standards. The tools vary in size, but they all need to dock on the cablehead. They have to be housed in a corrosion resistant and pressure tight shell. Only few tools work without electronics. Those using electronics must ensure enough lifetime for the sensible devices since temperature resistant electronic equipment is very rare. One support is keeping the heat of the reservoir outside by insulation with Dewar flasks. Another one is the provision of a heat sink either for a limited time span with phase change materials or without a time limit by using an active cooling system, based i.e. on the principle of the compression refrigeration machine. The power supplies for the electronics and solutions with sufficient bandwidth for an intensive online communication are only two of many more examples for further features, needed for almost every tool.

ZWERG is the German translation of dwarf, the small miners in many tales. The idea of the ZWERG project, running since the year 2010, is to provide a common platform for all kinds of logging jobs. Like a dwarf, ZWERG can bring different tools into the borehole and use them. Of course the machine will need the adoption of specialized equipment, which always is an engineering task. ZWERG is an open source project at its start. Many basics have been developed and evaluated, which will be published on the ZWERG website. The information given is multi layered, as the housing example shows: On the website the equations and rules for the dimensions are listed. Further an estimation for the material is made which goes beyond the suggestion of Inconel alloy 718, which is widely used in the industry. It is also mentioned where that material may be bought in the correct dimensions for a 200°C and 60 MPa environment, which is found in 5km deep wells in Central Europe. In addition an indication of the costs is given. Finally you can find blue prints of construction details like the interface to adjacent devices.

The open platform ZWERG is ready for use. If multiple designers use it and publish their experience on the ZWERG website, it will become less difficult to develop a new probe. More affordable borehole probes will enlarge the knowledge that is so important for geothermal industry: What do we find down under our feet and how can work be done in that hardly accessible and rough environment?

1. INTRODUCTION

Engineering a geothermal well is very complicated and expensive. Everything has to be done from uphole and remotely controlled. Unfortunately tiny dwarfs are only concepts in mythology. Therefore scientists must use logging and remote handling tools to explore the boreholes and work within them.

Common logging tools from the big oilfield service companies and some smaller and younger companies around the world are:

- measuring pressure and temperature
- caliper measurement
- natural gamma radiation detection
- casing collar locators… and many more.

Traditional oil and gas production is done in depths with ambient temperatures of about 120°C. Therefore logging tools for oilfields do not have to withstand the temperatures of geothermal brine and many of them refuse the geothermal job. In consequence hot wells can not be examined as detailed as oil and gas wells. The lack of knowledge is also arising out of the fact that in regard to the expected profit of the well the costs of examination are unaffordable.

Considering the problems in public acceptance of the geothermal technology in Germany and especially in the Oberrheingraben, it is extremely important to heavily increase the quality assurance. This starts with better public relations which depend to a high degree on secured knowledge on the well and its surrounding. It is evident that the experts should have multiple series of measurements before they plan repair works after an incident. Of course they will need tools for an intervention.

This paper describes the geothermal probe toolkit named ZWERG. The ambition of the ZWERG-project is to ease and speed up the development of probes with new sensors or probes for remote controlled repair work.

The environmental parameters of ZWERG have been chosen close to those of Soultz [Genter 2012]:

- borehole depth: 5000 m
- open hole diameter: 8 ½ inch = 215.9 mm
- max. ambient temperature: 200°C
- max. pressure: 600 bar = 60 MPa

2. COMMON CONCEPTS

Looking at a couple of sketches of possible geothermal probes it is shown, that all of them have many similar demands, as different as their missions might be [Isele 2013].

2.1 Borehole Cameras

Several rovers are exploring the Mars and send pictures of its deserts down to earth [Bell 2008]. This seems to be the first interest when arriving in a new world. Why don't we do this in deep wells regularly? There are three main technical reasons:

- While drilling or shortly afterwards, the borehole is filled with non-transparent mud.
- Camera chips are heat sensitive and work only up to about 115°C.
- Data transfer of at least 1 Mbit/s through a wireline of 5 km length is a technical challenge.

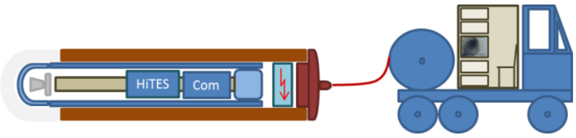

Figure 1: Modules ("bricks") of a borehole camera[1]

The overall system of a borehole camera will not work without wireline handling, a control desk, a power supply, a probe housing, insulation devices, electronics and software (figure 1). The software modules are used and reused as the hardware modules within the ZWERG framework.

2.2 Sampling Probe

Most available sampling probes use a piston which is moved by the reservoir pressure as soon as the inlet valve is opened. The inflow speed is controlled in order to prevent boiling of the sample. Sometimes the pressure on the sample is increased after closing the inlet valve to compensate decreasing temperature while moving out of the borehole. There is a proposal [Fichtenkamm 2012] for a sampling probe capable to control pressure and temperature of a sample while ascending.

In these probes it is an obligation to measure at least temperature and pressure in the well and in the sample. A sampling probe is a good example for a probe that has to be able to be fixed to other probes via a standard coupling in order to get more samples in one run.

Like the borehole camera the sampling probe needs a wireline, the handling of the wireline, a control desk, the power supply, a communication module, heat management and a motor with a motor controller etc. (figure 2).

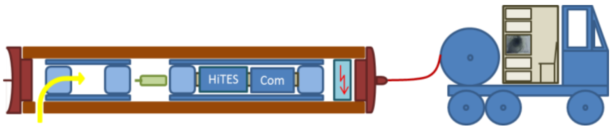

Figure 2: Modules ("bricks") of a sampling probe

2.3 Tracer Detector

It is always assumed that the geothermal brine flows from the injection well to the production well through the geothermal heat exchanger in the geology of the underground, but there have been many surprises. Better models can be established, when the place of the first breakthrough can be localized and the mass distribution of the incoming tracer along the production zone can be measured.

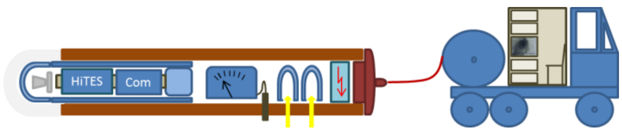

Figure 3: Modules ("bricks") of a tracer detector

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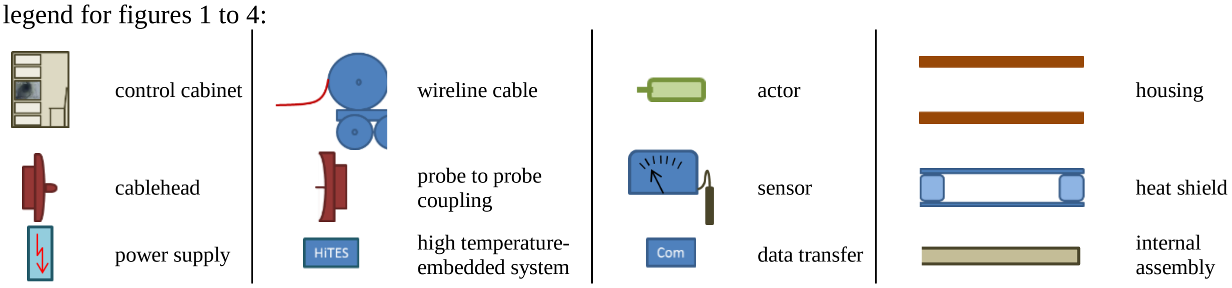
[1] legend for figures 1 to 4:



A tracer detector could be a combination of a borehole camera, a multi sampler and a measuring probe. This probe can be lowered to any place in the production zone. It waits there until sensors detect incoming tracers. From that time on, multiple samples may be taken.

Like the other probes, the tracer detector needs housing, power supply, control devices and so on (figure 3).

2.4 Casing Repair Probe

Casing repair robots are very common in horizontal ducts. Sewer repair systems use different concepts to fix sewers which lose water or those which have ingress of water. It is a known problem in Soultz that there is a casing restriction at 3904m in GPK2 where "cold" water enters the production well [Genter 2012, Tischner 2006]. Maybe the problems in Landau also arise from water finding a wrong way out of the injection well [WFG, GtV 2014]. Those leakages have to be plugged.

Even though there is no decision about the casing repair concept it is obvious that the probe will use many of the already mentioned "bricks" (figure 4).

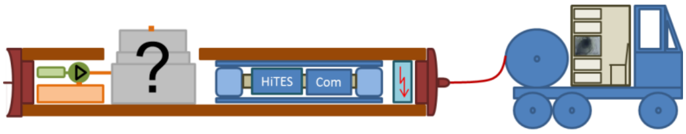


Figure 4: Modules ("bricks") of a casing repair probe

3. PLATFORM STRATEGY

There are many strategies to design new products. The goals are innovative, competitive products of high quality. In the case of geothermal probes financial aspects can stay behind the need to solve an existing problem, but quality is still an important aspect since tools with a low reliability might increase problems of a well instead of finding answers.

Koufteros, Vonderembse and Jayaram [Koufteros 2005] discuss the benefits of Concurrent Engineering, which brings together teams with different professional backgrounds sometimes involving suppliers and customers for new product development. Concurrent Engineering speeds up the design and production process. Trouble at the interfaces between mechanical parts and electronics or between designers and production is decreased.

Pahl and Beitz [Pahl 1986] taught systematic design by dividing the overall system into many subsystems. After searching for concepts for each subsystem, the synthesis of the modules leads to the final design. While this can be done on a conceptual level, it can also be done on a hardware level, where the modules are already produced. This implies that the function of the module and the interfaces to other modules are clearly described. The modules become black boxes. The effect is a simplification of the design process.

The idea of a platform strategy became very popular through the production philosophy of Volkswagen and other car companies [Muffatto 1999]. Many "customized" car models are built on the same chassis hidden under and behind the colorful makeup of the car body. This allows very much engineering effort for the platform parts. The components may be optimized in weight and security for instance. The production process can be optimized due to the high production quantity. This will lead to a very high quality product with a reasonable prize.

Volkswagen is improving the platform strategy by a modular concept with so called carry-over parts (COPs) [Winterkorn 2011]. Very similar functions have to be realized all over a car not only in the chassis. Examples might be seat belts, door locks, driver assistance systems etc. Many of those things are independent of the car design and can be used in different car concepts.

One might argue that putting together predefined modules can not lead to an overall optimized design or it will bear very similar cars. Sometimes this can be true. In geothermal probes space is very constrained and it could be that a module does not fit very well. But anyway, as shown with the examples above, there are many common elements needed for almost any probe. These elements are the "bricks" in the ZWERG-toolkit. Standardizing them will give developers a framework that leads to quick results. This framework forms constraints that might sometimes handicap a new design. Much more often it will help to focus on the main new objective, the new sensor for instance. There are so many questions in designing the toolkit modules, but they are all answered when the modules are ready to be used. As an example: The housing has to withstand the external pressure and the corrosive surrounding. The parts of the housing have to be screwed together. How is that done? Which thread shall be used? What about the sealing materials? Where can a supplier be found? What about costs and so forth.

Using the ZWERG toolkit as a platform answers many questions. Even so a logging tool can hardly be compared with a mass product like a car, it is worth using the car industry concepts. Actually it is even more important to find ways to reuse modules when building very small series than for mass product producers, since design and developing costs are split on very few produced modules. Using something twice (almost) cuts costs per piece in halves. In a non-competitive environment where different institutions try to solve problems in the first place, instead of earning money it is very much desirable to make an "open source" or "open hardware" project out of the ZWERG toolkit.

4. BRICKS

Proposing a design approach basing on predefined modules implies that somebody has to provide a couple of modules to start up with. This is done within the ZWERG project of the Karlsruhe Institute of Technology (KIT). The "bricks" of the toolkit will include basic elements like a probe housing or insulation equipement and more sophisticated elements as high temperature microcontrollers or motor controllers. Some of them will be introduced a bit broader in the next chapters.

4.1 Housing

The ZWERG housings will have outer diameters of 95 mm and 170 mm. They are machined out of a non-corrosive material with an extremely good yield strength. It was shown how that influences the space inside the probe [Isele 2013]. After many considerations, Inconel 718 alloy was chosen. About one half of the metal is Nickel, about 20% is Chromium and around 10 to 20% Iron (plus NB, Mo, Ti etc). At a temperature of 200°C its yield strength is about 843 N/mm². For an ambient pressure of 600 bar, the thickness of 95 mm (outer diameter) pipes has to be 8 mm. The remaining space is a cylinder with a diameter of 79 mm (figure 5).

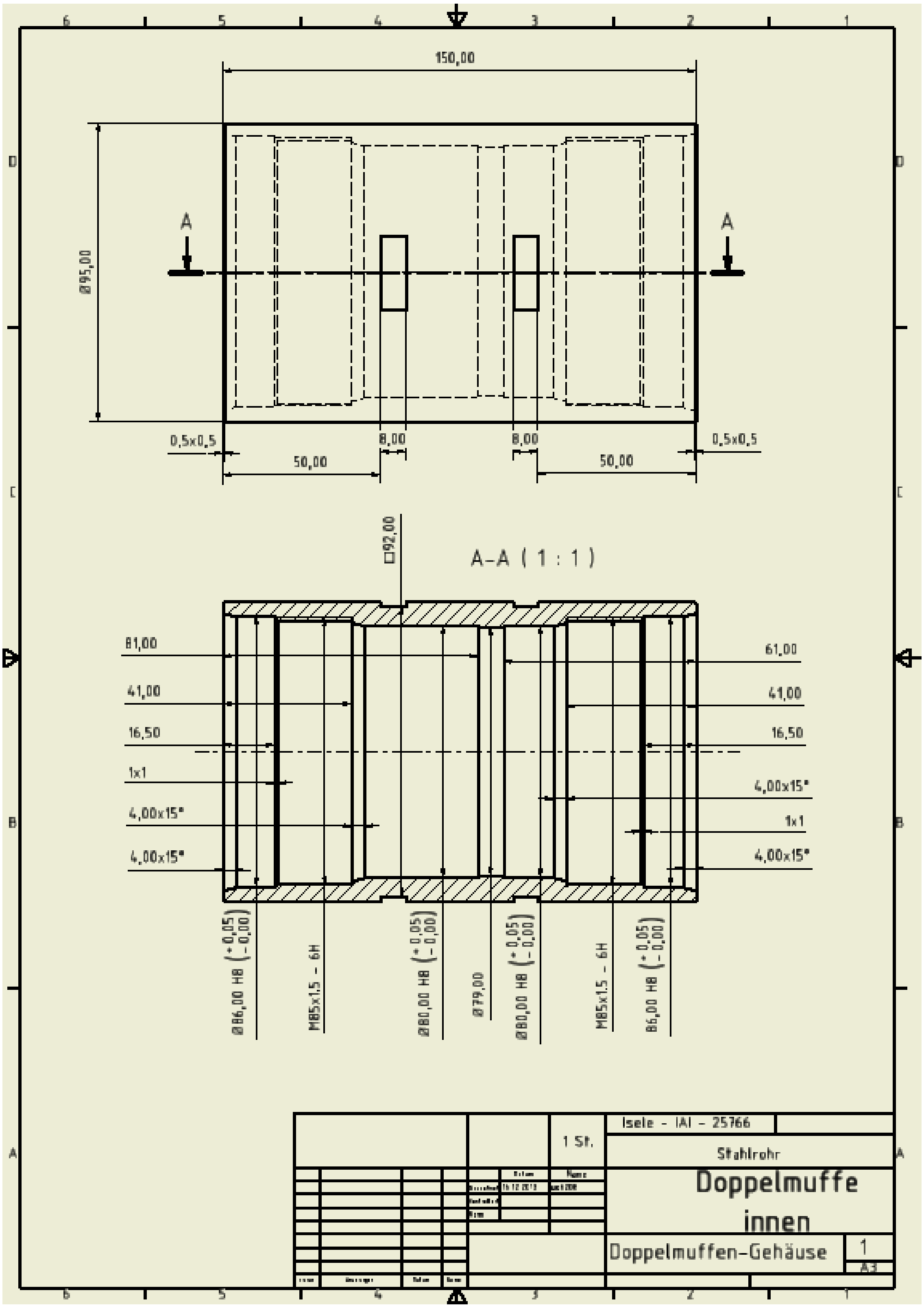


Figure 5: a blue print of a very short housing. The area with an inner diameter of 79 mm may be lengthened as needed

Unfortunately Inconel 718 is a material common in the oil and gas industry but not for steel suppliers. Therefore there are no catalogues where buyers may choose pipes and rods in different dimensions. For this reason buying Inconel 718 is time consuming and expensive. As can be seen in Table 1, there are huge price ranges; so it can be worth searching a bit.

Table 1: Costs for Inconel 718 pipes and rods from Germany (I – III) and China (IV – VI)

Type	L (m)	OD (mm)	t (mm)	ID (mm)	m (kg)	I (€)	II (€)	III (€)	IV (€)	V (€)	VI (€)
pipe											
170	6	168.3	14.2	139.9	324	74 220			26 602	26 603	21 639
170	6	168,3	19,05	130.2			43 860				
95	6	101.6	11	79.6	147	36 600			12 115	12 582	10 623
95	6	101.6	9.5	82.6			20 850				
95	6	101.6	17.5	66.6	218	36 600			17 894	17 894	15 691
95	6	101.6	19.05	63.5			29 520				
15	9	16	2	12	6	27 000	32 400		525	846	442
5	90	6	1	4	11	31 500	36 900	14 720	936	2 641	811
rod											
170	6	168,3			1064	69 000			35 101	25 427	33 111
170	6	180					47 800				
95	5	95.25			284	15 000					
95	5	101.6			400.6				12 791	10 135	12 066
95	5	105					13 221				
15	9	16			14	990	680		476	463	494
sum						290 910	225 231		106 439	96 591	94 931

OD=Outer diameter, t=Wall thickness, ID=Inner diameter, L=Length, m=Weight

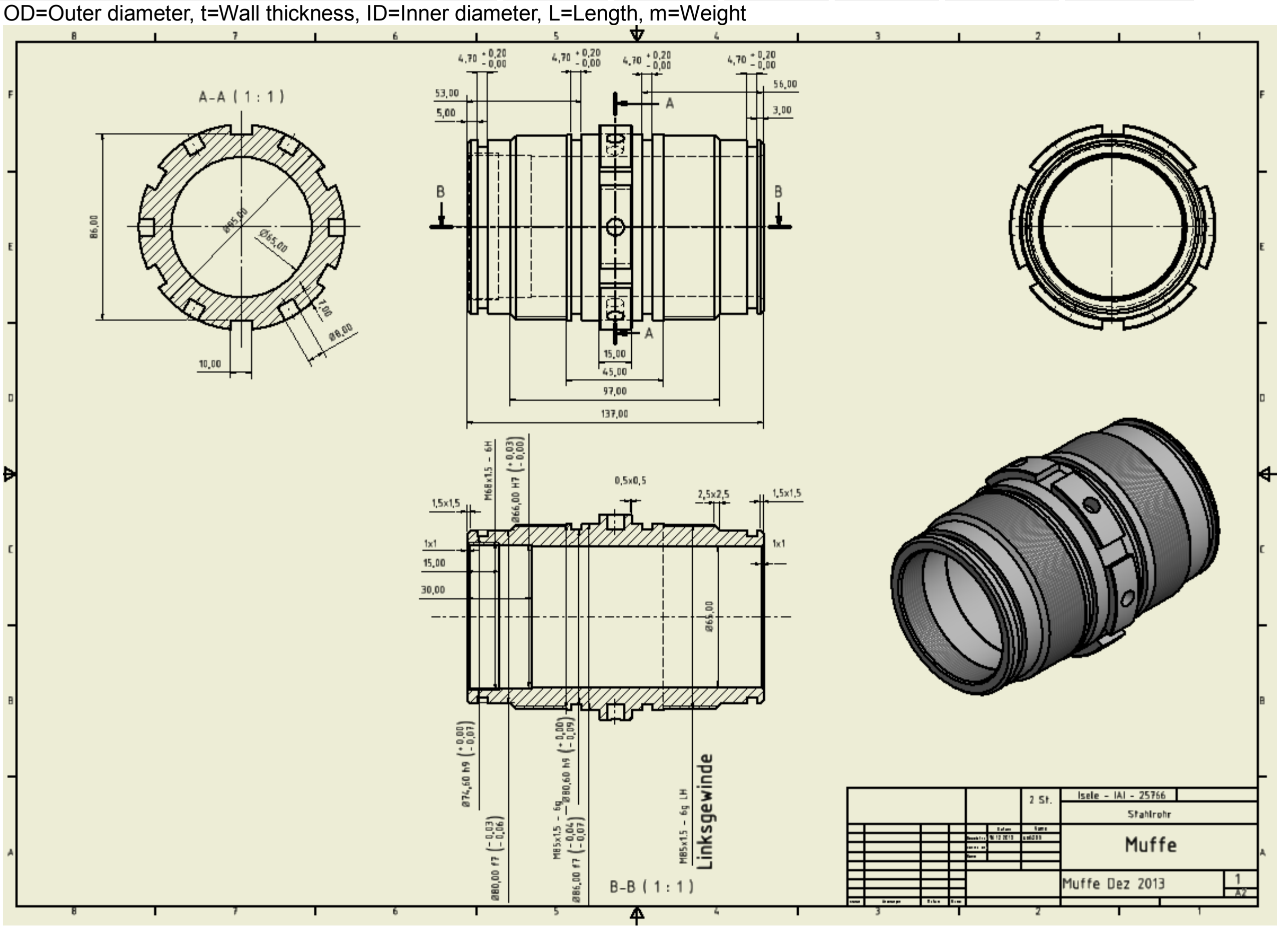


Figure 6: Blue print of a ZWERG-95 mm-joint (version December 2013)

4.2 Joints

The joint for the connection of two housing elements is basically an easy module (figure 6). It shows two threads, one on each side. It is important that one of them is a right-hand thread while the other one is a left-hand thread. This way, the housing modules can be connected almost without rotation relative to each other. The only rotating thing is the joint. In the middle there are counterparts for tools to tighten up the connection. The insertions for the four O-ring seals are arranged in a way that not all of them have to be compressed at the same time when joining two housing segments. At the inner diameter there is a thread which could be used to mount something. This could be used to fix modules in axial direction.

Experiments with this joint showed, that the threads should be chosen a bit larger. With the design of figure 6 the threads are too sensitive for dirt or even very small deformations. The length of the thread should be reduced. On one side a long thread gives some security on the other side it is annoying to screw too many turns. The most important change will be a longer seat that centralizes the three partners before the threads come to action.

4.3 Heat Management

The reason for drilling geothermal boreholes is to find hot water. Working in those boreholes will heat up the probe to an extent that becomes dangerous for electronics. Standard electronic components will survive ambient temperatures up to approximately 70°C. Components for the automotive or military industry are often capable to withstand 125°C. Above that, there is only a very small market segment and only a few providers. Therefore one main aspect of ZWERG is the heat management.

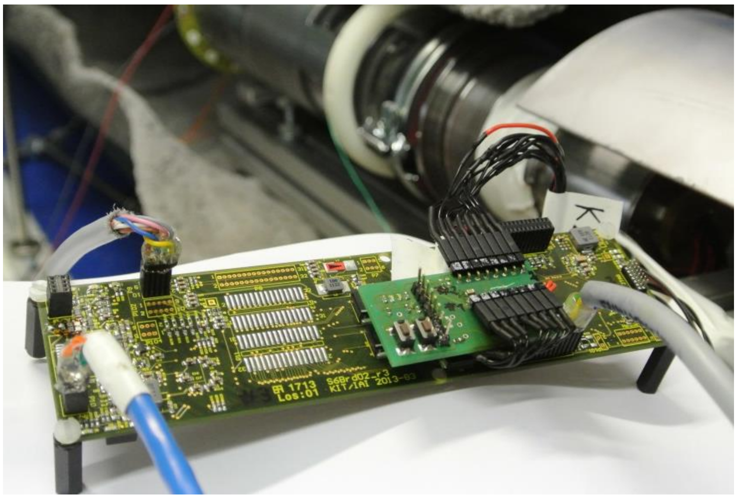


Figure 7: The HiTES-FPGA-brick for ambient temperatures up to 125°C in a test environment

The first thing to do is to keep the heat of the reservoir out of the probe. The best insulation that can be achieved is vacuum insulation. The ZWERG toolkit contains Dewar flasks as “bricks”. This is basically a double wall vessel made out of two pipes fitted together at their ends with two flanges. In the evacuated space between them, there is an aluminum foil that reduces heat transmission. Since the outer pipe will get hot while the inner pipe stays relatively cold, there must be an arrangement to equalize the different thermal expansion. A technical challenge is to evacuate and close the vessel through the very small area on the two flanges.

Downhole operations with short trip times can be managed by storing the heat passing through the insulation and produced by the electronics inside the probe in a medium with a large heat capacity. It makes sense to use a phase change material (PCM) in order to use the sensible and the latent heat. There are different PCM materials on the market but ice is a good choice. It can be replaced for the next trip relatively easily. If tools will only be needed once in a month, than a PCM could be used that will “reload” itself just while the tool cools down to room temperature.

If the logging tool has to stay downhole longer than a few hours, the amount of PCM needed would become too large. In the **CO**b**OL**d project a cooling machine will be developed. This will be a future ZWERG “brick” [Holb 2015, Holb 2014].

In some cases – thinking on high enthalpy wells for instance – it will be extremely desirable to work without cooling or with a temperature on the cold side of more than 70 or 125°C. ZWERG supports that with HiTES modules (High Temperature Embedded Systems). There is the HiTES-FPGA “brick”, a 125°C board, basing on a Spartan-FPGA (Field Programmable Gate Array) (figure 7). Another board for temperatures up to 200°C basing on a Texas Instruments microcontroller is the HiTES-µC “brick”. With this board an application is realized to drive a brushless DC motor. Half bridge drivers and Mosfets on a second board are CISSOID components.

4.4 Heat Transport

Geothermal probes tend to be long and slim tools. A heat sink with a certain capacity will need some space and fill a part of the probe completely. While building a first prototype of a probe with the ZWERG toolkit the best design turned out to be a version, where all the electronics are concentrated on one copper plate in one housing segment while the heat sink is located in a second housing segment. With this design there is a minimum of cables running through the PCM segment (actually only 2 wires). But this design leads to the problem that the heat has to be transferred from almost one end to the other within the probe.

Using fans is an approach, when there are smaller hotspots and plenty of space to blow away the hot gas/air. This technique might be useful, when heat has to be transferred between components with a relative movement to each other. Its disadvantages are the low efficiency, the additional heat from the electricity consumption of the fan and the additional moving part in the probe, which decreases the reliability. Using a fan will be an exception.

One could also think of a water cooling system or more sophisticated attempts like a slurry ice cooling [Kauffeld 2010]. This is an efficient method to take away heat from where it threatens electrical devices. This concept will need an active pump and will consume energy, too. Additionally it will need two pipes running through the joint in between two housing segments. This will make the assembly and repair work very difficult.

Good solutions are heat pipes. "The heat pipe is a device of very high thermal conductance. For example, a temperature difference of 900°C is needed to transfer 1 kW heat across a 30-mm-diameter 1-m-long copper rod. A heat pipe of the same size can transfer the same amount of heat with a temperature difference of less than 10°C. This indicates that the heat pipe can have a thermal conductivity 90 times higher than that of a copper bar of the same size." [Faghri 1995] Heat pipes may have very different shapes, but the standard is made up of small copper pipes with thin walls. They are evacuated and filled with a drop of water. Capillary effects are used to spread the water in a thin film all over the inner surface of the heat pipe. When the heat pipe is heated up somewhere, the water will turn to vapor consuming the latent heat of evaporation. As the pressure will rise on the spot of the evaporation, the vapor will move through the heat pipe very quickly. When there is an area with a surface temperature beneath the boiling temperature, the vapor will condense. The latent heat is transferred to the heat pipe shell.

A small example will give an idea of the difference between heat pipes and thermal conduction through rods. The basic equation for thermal conduction is:

$$Q = \frac{\lambda\ A\ t\ \Delta T}{l}\ [Joule] \qquad [4.1]$$

with
Q - transported heat
λ - thermal conduction coefficient
A - cross sectional area of the rod
t - time
ΔT - temperature difference of both ends
l - length of the rod

Assuming the heat of a 10 Watt consumer has to be transported over 600 mm with a single metal rod. What will be the diameter of the rod? 10 Watt consumption means that every second 10 Joule of heat will be produced. This is calculated by transforming [4.1] to:

$$d = 2\ \sqrt{\frac{Q\ l}{\pi\ \lambda\ t\ \Delta T}} \qquad [4.2]$$

with
d - diameter

Table 2: Diameters of the rods for various metals and different ΔT

		ΔT		
	λ	10 Kelvin	20 Kelvin	50 Kelvin
stainless steel	15 W/m K	226 mm	160 mm	101 mm
copper	384 W/m K	45 mm	32 mm	20 mm
aluminum	220 W/m K	59 mm	42 mm	26 mm

Compare these diameters with the amount of water that must evaporate, to consume 10 Joule. The basic equation for heat consumption for evaporation is:

$$Q_{evap} = r\ m\ [Joule] \qquad [4.3]$$

with:
Q_{evap} - heat for evaporation
r - specific heat of evaporation: 2256 kJ/kg (H_2O at 100°C)
m - mass of evaporated fluid

This may be transformed to:

$$m = \frac{Q_{evap}}{r} \qquad [4.4]$$

This leads to the result that only 4.4 mg/s or about 16 grams per hour of water have to evaporate. [Faghri 1995] "Heat Pipe Science and Technology" is a 908 pages book, but to give an idea what is happening: those 4.4 mg of water will turn in 7.36 cm³ of steam.

Inside a heat pipe with an inner diameter of 7 mm this volume needs 19 cm in length. Therefore one can imagine that an 8 mm heat pipe with a performance of 55 Watt [Quickohm 2014] has a high gas flow.

5. EXAMPLES

5.1 Video Inspection Probe: GeoKam

The usefulness of the ZWERG platform has been evaluated on the GeoKam project [Spatafora 2014, Spatafora 2015]. GeoKam is an online video tool for deep geothermal wells and it is far more than just a mechanical device. Important components are the fast data transmission through a standard wireline cable using software defined radio techniques and the picture compression with the ZWERG HiTES-FPGA controller. Field tests with GeoKam will take place in 2015 in a borehole near Munich.

GeoKam is an good example for the power of the ZWERG concept. The following “bricks” are used:

- 1x rear flange with wireline connection
- 3x housing modules for uncooled space, PCM container and the housing for the electronics
- 2x joints
- 2x Dewar Flask for insulation
- 1x PCM container
- 3x Heat pipe for heat transfer
- 1x Mounting plate for electronic boards
- 2x HiTES-FPGA for the data transmission modem and the video compression
- 1x axial divider, that forms two containments in the probe
- and lots of other devices like cables, connectors etc.

Of course there are other components needed for a video probe:

- 3x camera + lens + lens adjustment system
- 1x rotating unit for the cameras
- 1x lightning
- 1x Dewar flask made of glass, to be able to look through
- 2x electrical connection through the housing for the power supply of the lights
- 1x housing with windows

So using the platform does not solve all problems. There is still much work to do for a running probe, but it simplifies the design tremendously.

5.2 Probe Cooling System: COBOLD

A new project called COBOLD (a relative of the dwarfs) will add the important cooling-system without time limitation to the toolkit [Holbein 2014, Holbein 2015]. COBOLD will be a refrigerator for downhole applications.

From the platform strategy point of view, COBOLD is special. It will not be a “brick” that can be stuffed in a housing “brick”. It would be too large. It will rather be a unit with the look of a probe. The compressor and the throttle will be placed in a housing “brick”. The heat exchanger for condensation will be formed of multiple pipes. At the rear end there will be a connection to a joint “brick” and an electrical connector to other probe components. On the other end there will also be an electrical connector and the joint “brick” but also an interface for the heat exchanger where the refrigerant evaporates. The compressor is of course not a ZWERG “brick” but the DC-motor that drives the compressor is the motor “brick” as is the motor driver basing on the HiTES-µC.

COBOLD is an example of a complex “brick” made out of many subcomponents and using ZWERG “bricks” by itself but it will be used in various probes like other “bricks”. It is the model for many other developments which can be useful for many applications, like:

- Casing collar locator “brick” (detecting the casing joints for position control)
- p,T “brick” (pressure and temperature measurement)
- camera “brick” (for example: camera looking onto a cone mirror; uphole computer used to “improve” pictures)

5.3 Steerable Centralizer: SOHLE

The geothermal brine – unless there is something wrong with the casing – is recovered out of the deepest region of the borehole. In many cases this region is run as an open hole without a steel casing. Because this is the place of production, its geology is of great interest. This is the place many logging tools have to work. However it is very dangerous to act there because the probability to get stuck is very high in that area. The probe could hook in the casing shoe or on any other obstacle.

Centralizers will be mounted to most logging tools to keep the tools near the central axis of the borehole. The arms of the centralizers are usually pressed to the borehole wall by springs. Because these centralizers should work from the top to the ground of the borehole and the borehole diameter decreases at the same time, the contact pressure increases. This notably increases the danger of getting hooked.

A way out of this dilemma is a steerable centralizer. This is a device with three arms which can be moved independently. These arms can keep the probe in the center of slim and wide boreholes with almost the same contact pressure. They can support probes that need to have contact with the wall or they can maneuver the probe to the opposite side in order to maximize the distance between the probe and a point of interest – when taking pictures for example. Most important however is their capability to push the probe away from troublesome obstacles which can be detected with the camera "brick" mounted on the rear of the probe. Therefore steerable centralizers are important devices for the secure access of the open hole, the place where it's all about.

The steerable centralizers will use the motor "bricks", the HiTES-µC "brick", the motor driver "brick" and many details from ZWERG.

6. CONCLUSION

It is very important for the future of geothermal energy provision that there are more affordable probes to investigate and work in deep geothermal boreholes. This way knowledge increases, some problems can be solved and the fears of the public might decrease which is a point with rising significance.

Looking on several probes, one can find many common components. This leads to the consideration of a platform strategy for geothermal borehole probes. So the ZWERG toolkit and some of its "bricks" are introduced.

Blueprints of the housing "brick" and the joint "brick" are presented. To fit the entire constraints Inconel 718 alloy is chosen as standard material. Since there are only few suppliers of rods and pipes made of Inconel 718 and none has a sufficient stock list, it needs some effort to get a couple of comparable offers. An example of difference in prices that vary by factor three is given.

Since electronic devices usually are heat sensitive, "bricks" for the heat management are introduced. While some rare devices may work at ambient temperatures of 200°C, others quit service at about 125°C or 70°C. The HiTES-µC "brick" still works at 200°C, the HiTES-FPGA "brick" has to be cooled down to 125°C.This can be done for a while by a phase change material or without time limitation by a cooling machine.

In one section, heat transfer concepts are compared. For ZWERG the best choice are heat pipes, devices transporting heat very much better than other technologies.

Some examples show what can be done with the ZWERG platform. The GeoKam probe is almost ready to be used in every day work for video inspection of deep wells. It illustrates how main parts of a probe can be made out of "bricks". The remaining parts are completed by individual designs. The active cooling machine COBOLD will be used as a "brick" but it is an example, how a larger, more complex "brick" is formed out of other "bricks" and individual supplements. The third example is the SOHLE project. Entering the open hole is often declared as an impossible thing because of the danger to get hocked on an obstacle. Since this is the place of biggest interest for geologists steerable centralizer arms are very important aids for downhole tools.

ZWERG is a platform or a framework for multiple downhole tools. If the keen idea will be successful to provide an open source toolbox used by many players in the geothermal community, a lot more knowledge about the underground could be gained and some repair tasks could be done by probes. Then in future it will be possible to manage different jobs with wireline tools instead of installing a work over rig or using coiled tubing. That would have the potential to save a lot of money.

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