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DEVELOPMENT OF A LOW COST NOVEL PT LOGGING TOOL FOR HIGH TEMPERATURE OPERATION (600°C)

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05.05.2020

Abstract

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Exploitation of super-critical water from deep geothermal resources can potentially give a 5-10 fold increase in the power output per well. Such an improvement represents a significant reduction in investment costs for deep geothermal energy projects, thus improving their competiveness.

In the previous European Horizon2020 DESCRAMBLE (Drilling in dEep, Super-CRitical AMBients of continental Europe) project it was demonstrated drilling of a deep geothermal well with super-critical conditions (>375°C, >220 bar) by extending an existing well in Larderello, Italy to a depth of around 4km. As state-of-the-art electronic logging tools could not operate reliably at these conditions, DESCRAMBLE developed and tested a novel pressure and temperature logging tool for these supercritical conditions. Target specification for the slickline operated tool was 8 hours logging operation time at 450°C/450 bar, limited by the critical temperature for the available battery technology used for the application. During testing in the supercritical well in Larderello, Italy in 2017, the tool recorded a maximum well temperature of 443.6°C.

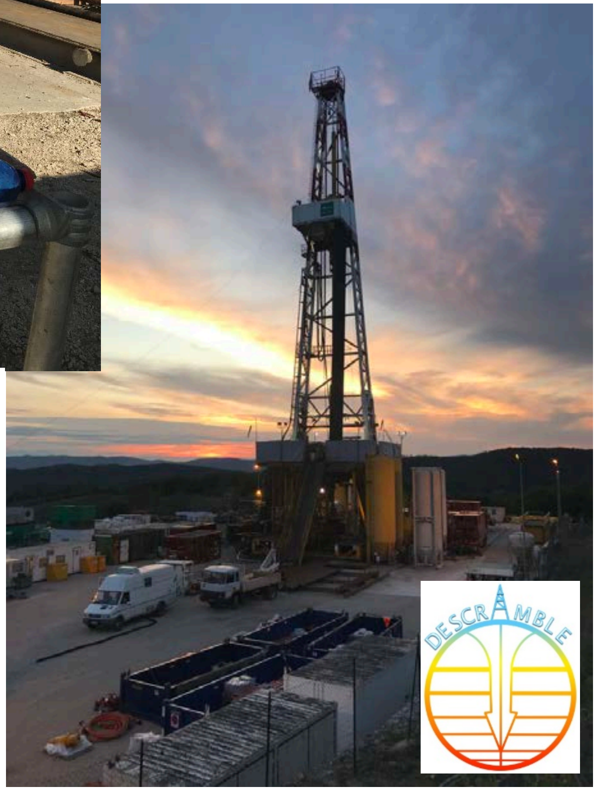
The instrument developed in the DESCRAMBLE project, although being state-of-the-art in its performance, was costly and advanced in addition to having a larger outer diameter than desired in for example slim-well applications. Therefore, there is a need for a simpler, lower cost version of this tool with a smaller outer diameter.

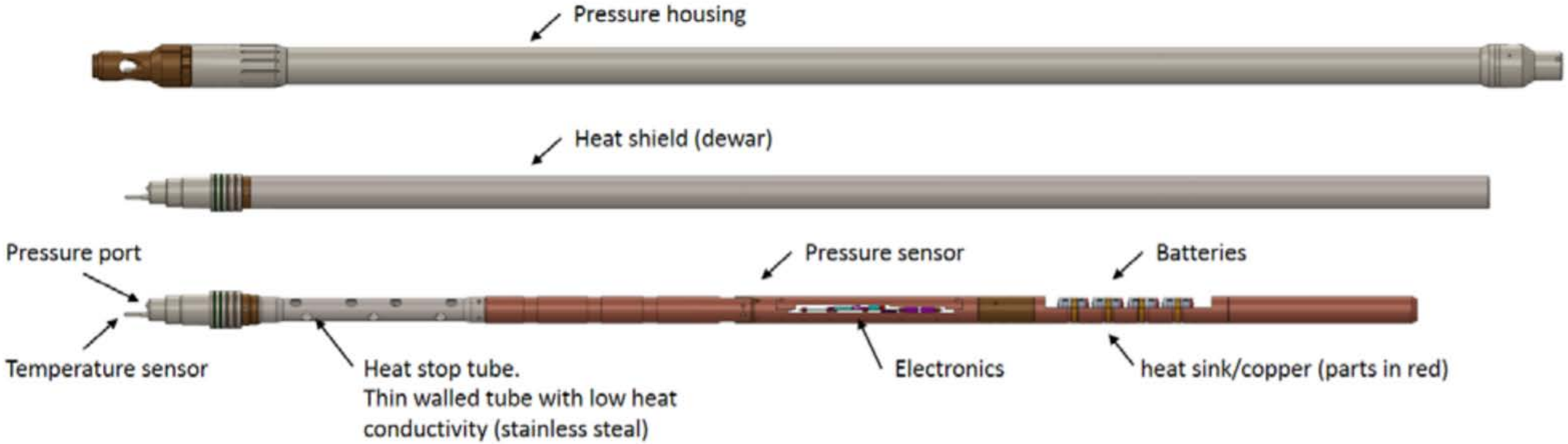
The tool being developed, based on the H2020 DESCRAMBLE project, consists of off-the-shelf high temperature electronics, sensors and batteries shielded from the environment by a heat and pressure shield (Dewar). The target specification for the tool is 600°C/500bar, with a shorter operational time than the DESCRAMBLE tool.

In this work, we describe the tool requirements and discuss the design choices made regarding mechanical parts, seals, electronics platform, sensors, and available battery technology. 3D CAD drawings and simulations of the thermal performance of the tool will be presented, as well as preliminary test results of the electronic platform combined with the sensors and batteries. Production and testing of the physical tool will not be within the scope of the project.

Introduction

This ongoing project named mini-DESCRAMBLE is based on the previous European Horizon2020 project DESCRAMBLE (Drilling in dEep, Super-CRitical AMBients of continental Europe)





Project Goals and Deliverables

Main Goal:

Design a lower cost, more simplistic version of the PT memory logging tool developed in the previous H2020 project DESCRAMBLE. Increase the maximum operating temperature of the tool from 450°C to 600°C in addition to reducing the outer diameter (OD) of the tool to allow for slim well applications.

Project Deliverables

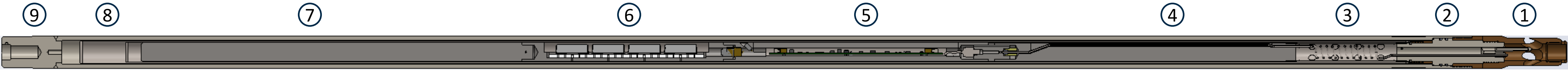
- 3D Drawings of tool
- Simulation of thermal performance
- Testing of electronics platform with external P&T sensors
- Investigate battery options for high temperature operation
- Publication

Tool Target Specifications

Operational Design Specifications	
Max External Temperature	600°C
Max External Pressure	600Bar
Outer Diameter (OD)	54mm (2.1")
Tool Length	2.6m
Tool Weight	37kg
Max Tool Operating Time @350°C	9h
Max Tool Operating Time @450°C	6h
Max Tool Operating Time @600°C	4h

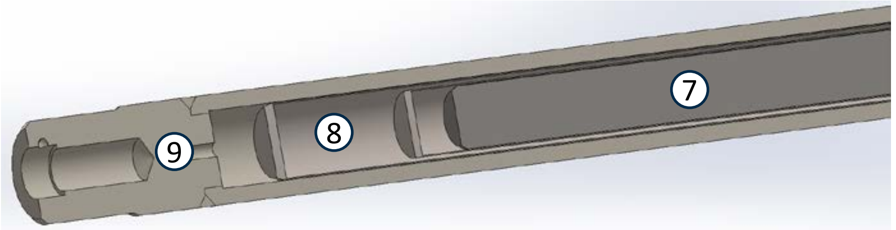
Measurement Design Specifications	
Temperature Accuracy	TBD
Temperature Resolution	TBD
Pressure Accuracy	TBD
Pressure Resolution	TBD
Sampling Rate	<1 SPS
Data Storage	32KB

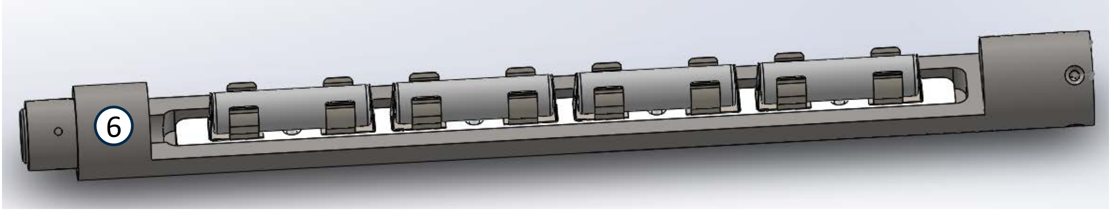
3D Model

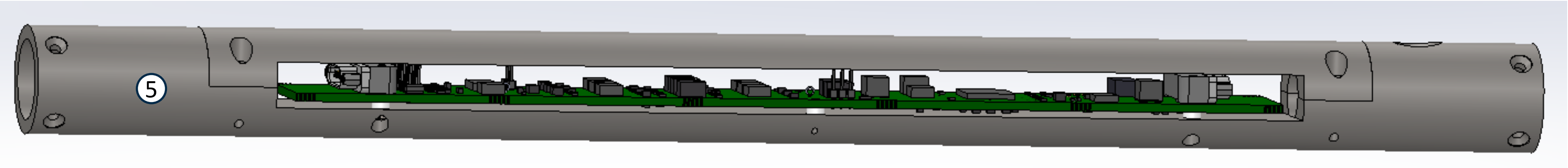


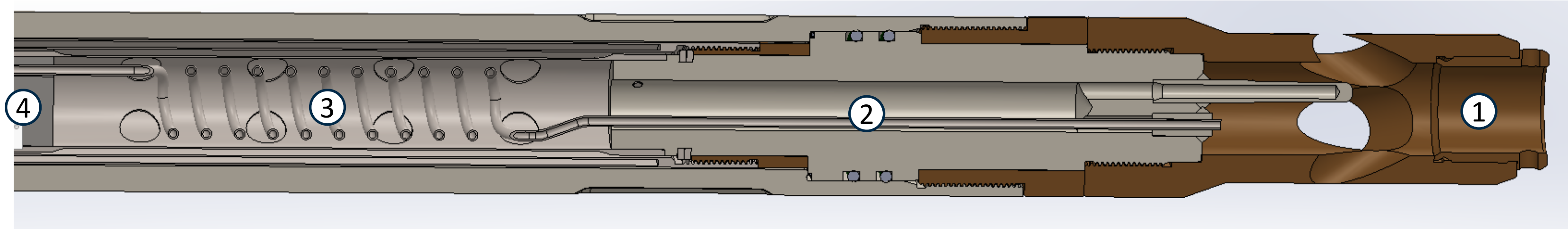
Tool consisting of the following main parts:

- Nose (1)
- Bulkhead (2)
- Heat Stopper (3)
- Heat Sink (4, 7)
- Electronics (5)
- Battery Holder (6)
- Dewar (8)
- Pressure Housing (9)









Electronics Platform: VORAGO HT-DAB-1

- The high temperature data acquisition system used in this project is the Vorago Technologies Kit HT-DAB-1. The aspect ratio is perfectly suitable for downhole logging tools as the PCB dimensions are 1.0 x 11.5 inches.
- All the components and the PCB itself are rated and tested for 200°C operation.
- The core of the board is the VORAGO VA 10800 ARM Cortex M0 microcontroller. It is a 32-Bit microcontroller manufactured with HARDSIL technology, offering superior operational lifetime, low leakage performance and latch-up protection at extreme temperatures up to 200°C.
- The board is supplied with 3.3V and the current consumption is around 35mA. An external oscillator sets the clock frequency to 50MHz. There are 3 ADCs, one of which is multiplexed with eight input channels, and 2 voltage references, one at 1.5V for the MCU supply, and one at 2.5V, available at the output.
- In addition, the board also has 2 memory chips: one 32KB SRAM for data storage, and one 128KB SRAM for programming. Considering an acquisition rate of 0.1 SPS (1 sample every 10 second), there is enough memory to store 8bit data from 3 sensors for more than 12 hours

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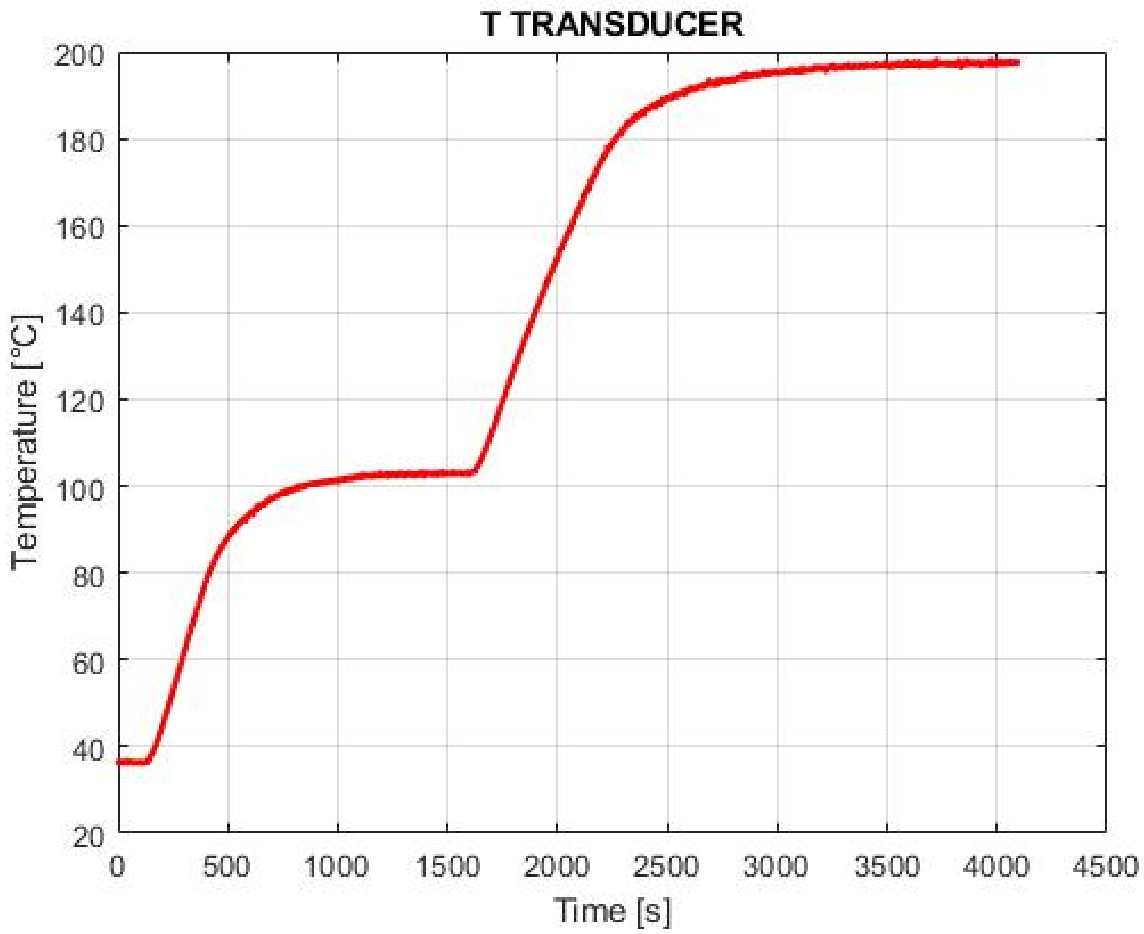
Transducer and Measurement Set-up

- In order to test the acquisition system, data from 2 transducers (temperature sensor and pressure sensor) have been acquired.
- The temperature transducer used is a THERMOSENSE Mineral Insulated RTD Pt1000 with Pot Seal, whose maximum operating temperature is 500°C.
- Temperature sensor is placed inside a TERMAKS TS8000 controlled oven, where the temperature can be regulated with a precision of 1°C
- The pressure transducer used is a KULITE HEM-375 SERIES with a measurement range from 1 to 500 bar.
- Pressure sensor is linked to a IKM PC705M pressure system calibrator, where silicon oil can be pressurized up to 700 bar.

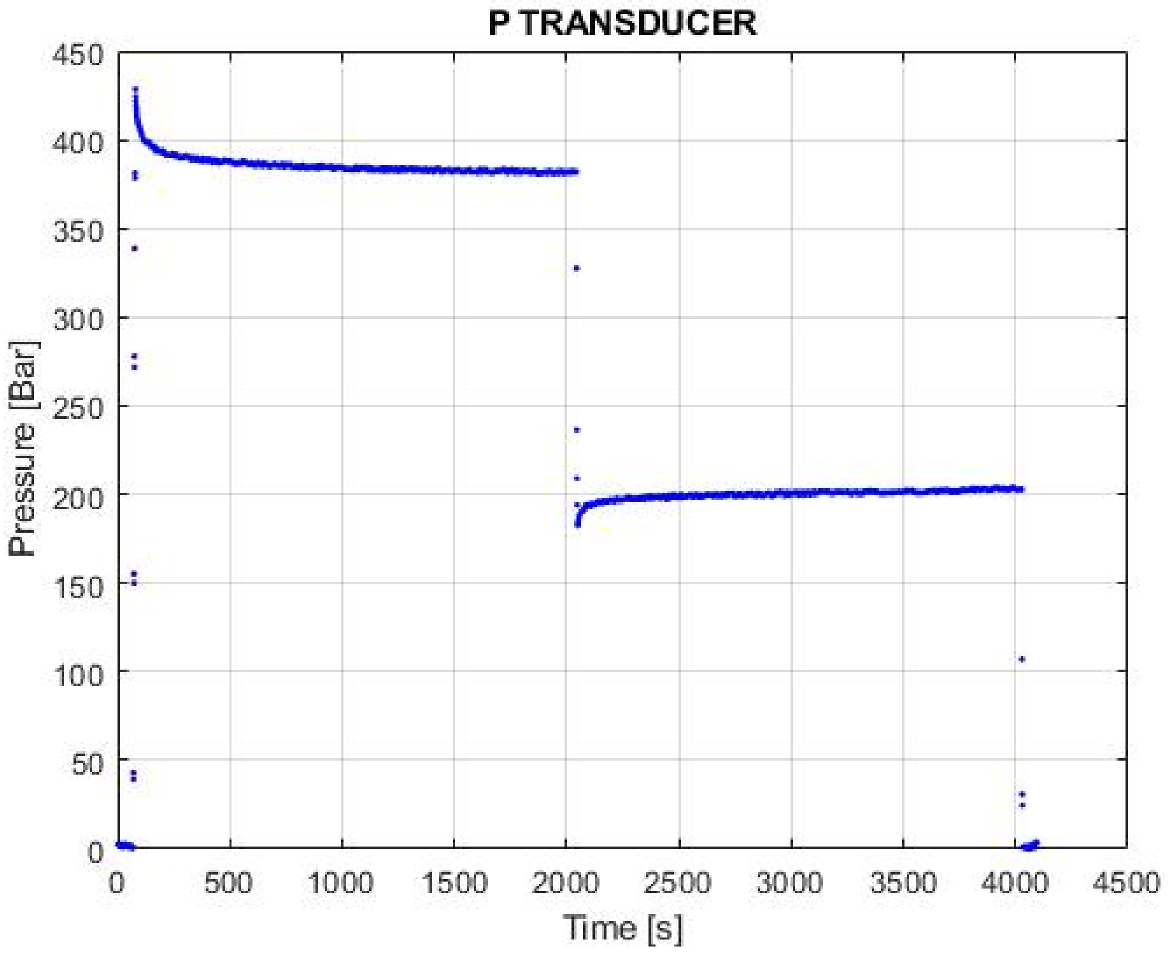
Results: Temperature Measurement

- The temperature transducer is connected to a resistive voltage divider, supplied by the 2.5V regulated voltage available at the output of the Vorago board.
- The voltage across the sensor is then acquired by the ADC0 channel of the Vorago board.
- Results of the acquisition of 4096 samples, with a rate of 1 SPS, are shown in the figure.
- The controlled temperature of the oven was changed by steps (35, 100 and 200°C). The discrepancy between the measured and the set values is due to the fact that our transducer is put in the center of the oven, while the oven reference termocouples are placed near the walls. The differnce is maximum 2%, comparable with the 1.5% oven spatial deviation declared.



Results: Pressure Measurement

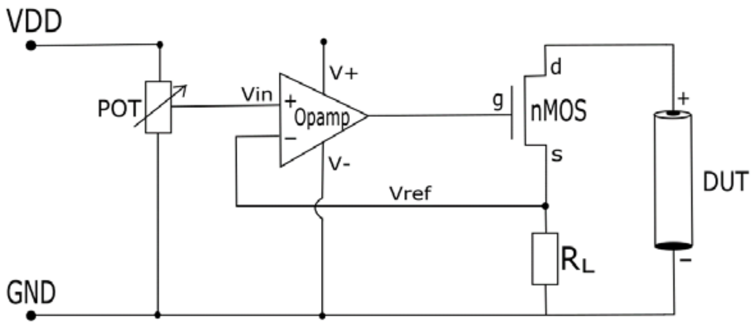
- The pressure transducer is supplied by the 2.5V regulated voltage available at the output of the Vorago board.
- Since the output of the transducer is differential, while the ADC inputs of the Vorago board are single ended, a high temperature operational amplifier in a differential configuration has been used to connect the pressure sensor to the Vorago board.
- The voltage across the sensor is then acquired by the ADC1 channel of the Vorago board.
- The results of the acquisition of 4096 samples, with a rate of 1 SPS, are shown in the figure.
- The pressure, was first manually increased from 1 bar to around 400 bar, then reduced through a valve to around 200 bar and finally reduced back to 1 bar.
- The pressure evolution inside the single step is due to the temperature variations that occur when a fluid is pressurized



Batteries

Investigating and testing different HT battery options depending on application and operating temperature

- Electrochem PMX165 (-20°C to +165°C)
- Electrochem VHT200 (+70°C to +200°C)
- Engineered Power LIRAA-165HT (-40°C to +165°C)
- Engineered Power LIRAA-200HT (+70°C to +200°C)
- Engineered Power LIRAA-225HT (+150°C to +225°C)

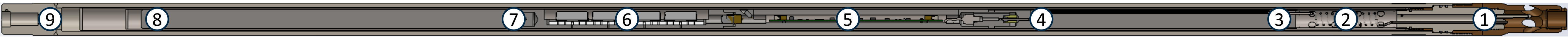


Vref = Vin => IRL = Vin/RL

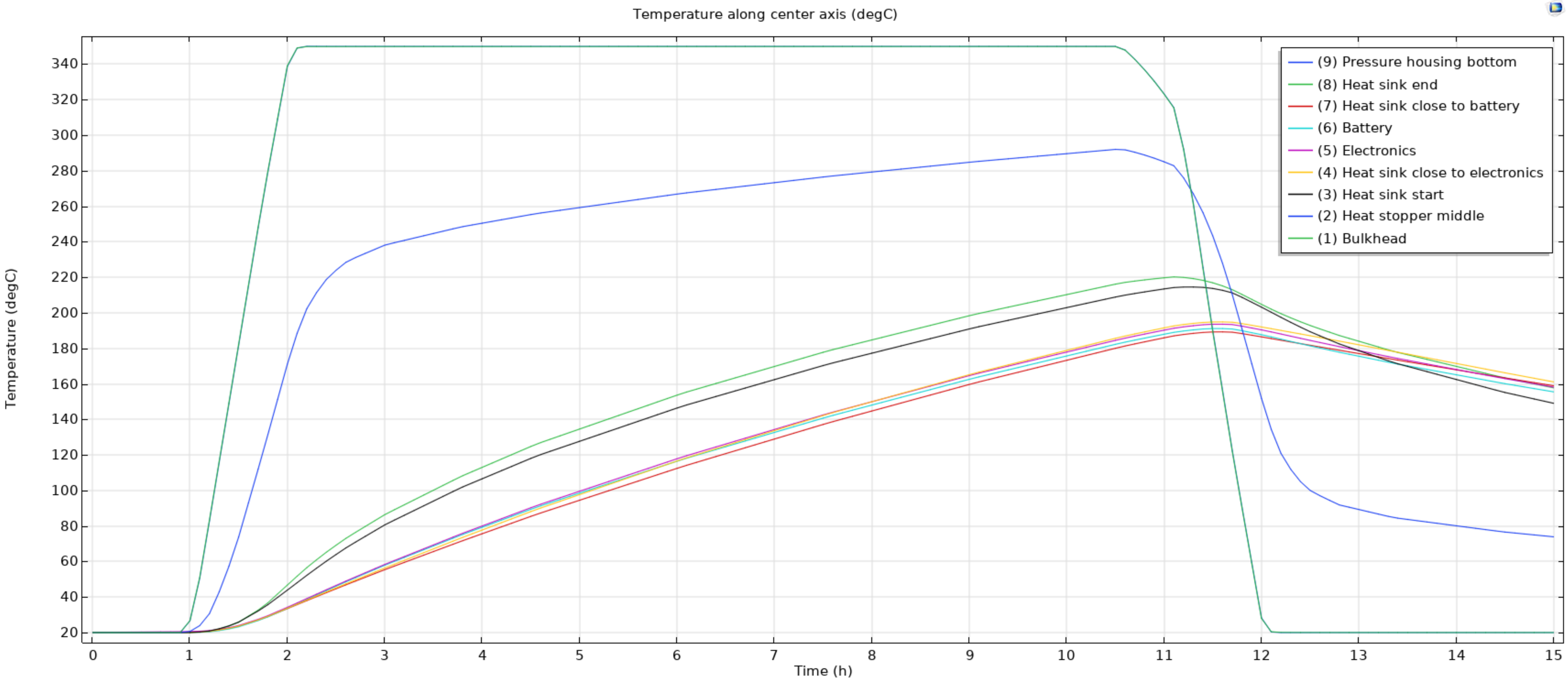
Thermal Simulations

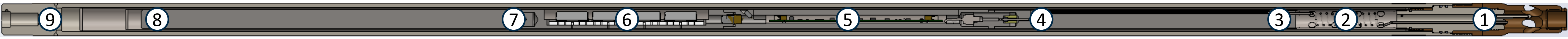
Thermal simulations in COMSOL is performed to validate the thermal performance of the tool based on the 3D model. Results show an estimated operational time at 350°C, 450°C and 600°C of 9h, 6h and 4h respectively.

Results from the simulations can be seen in the next slides.



Thermal Simulation (well-temp 350°C)





Thermal Simulation (well-temp 450°C)

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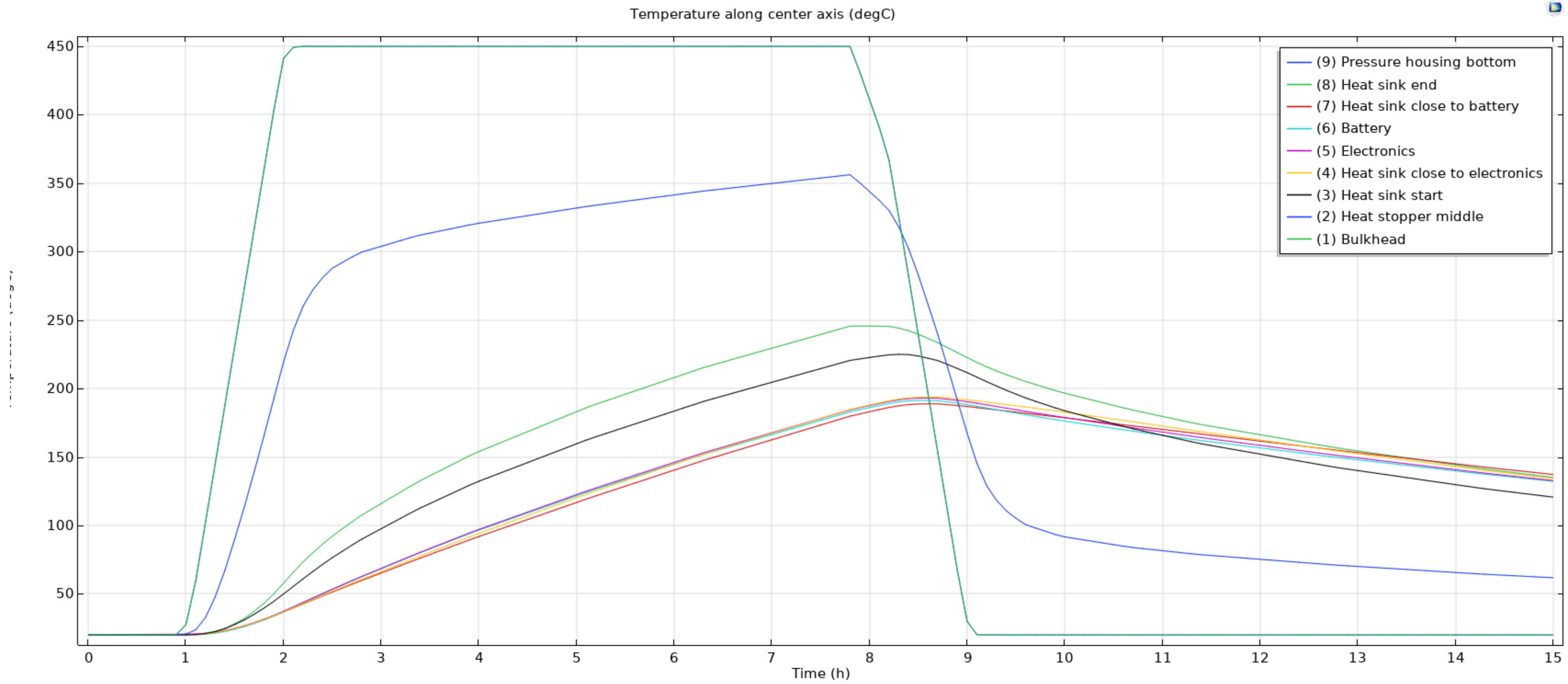

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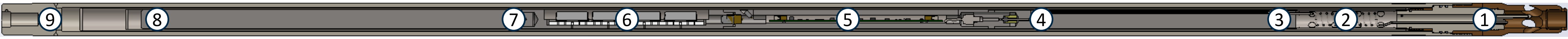
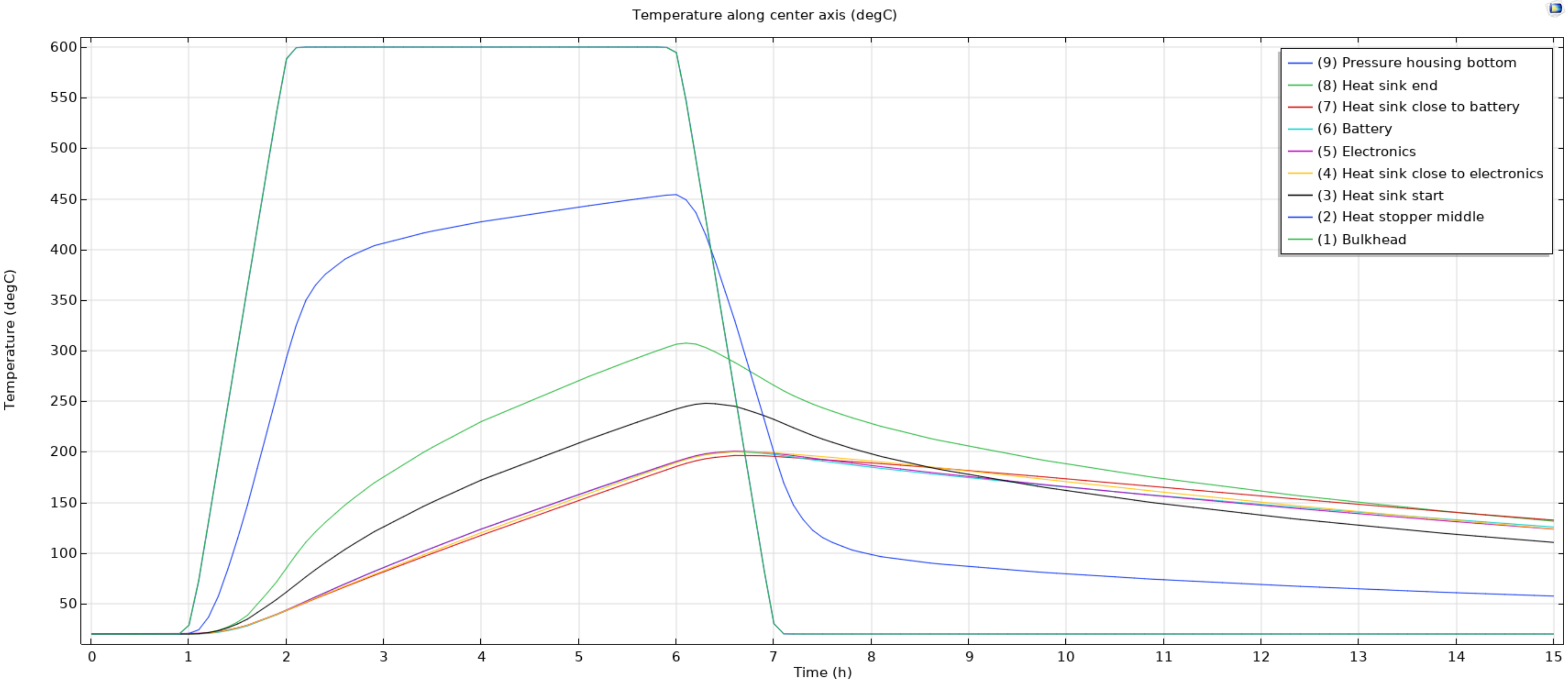


Thermal Simulation (well-temp 600°C)



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