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COMSOL
CONFERENCE
2017 ROTTERDAM

Heat Transfer Modelling For Thermal Stimulation Of Near Borehole Using COMSOL Multiphysics

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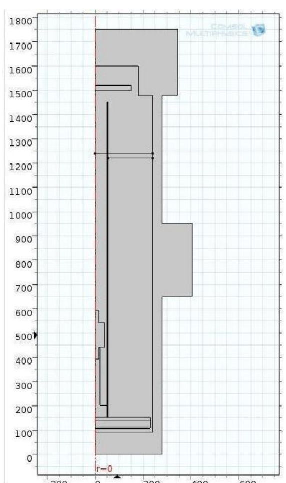
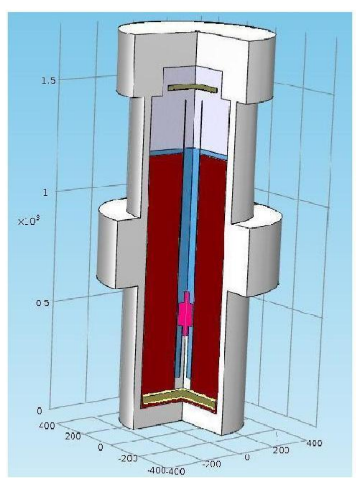
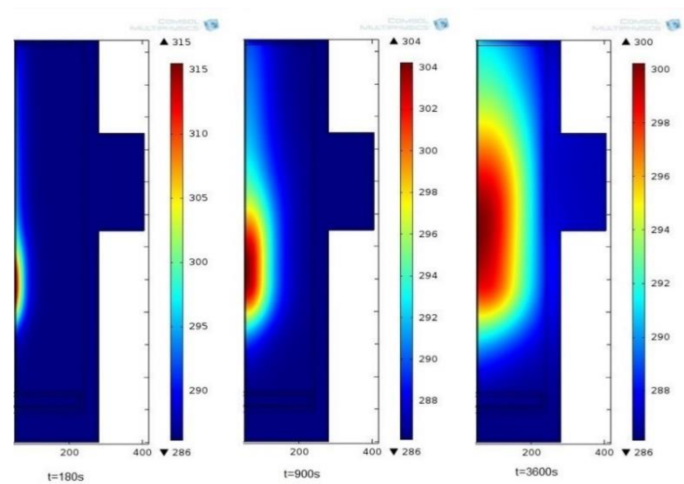
Rotterdam, 19.10.2017



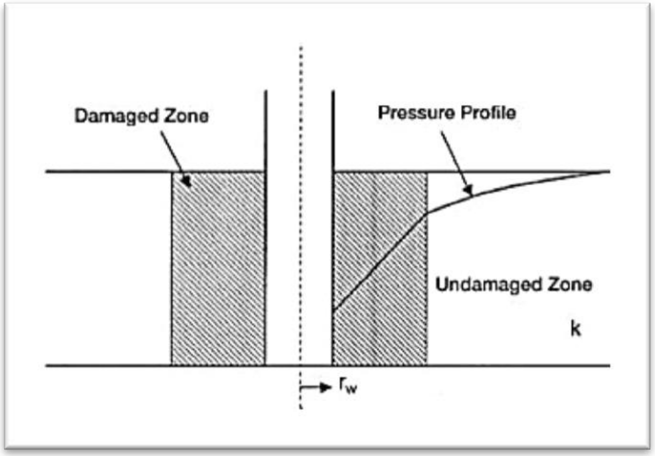




Overview

1. Introduction and motivation

- **Problem**
  - Formation damage near borehole due to highly viscous oil deposits
- **Motivation**
  - Permeability enhancement
  - Use of a new thermal process



- **Aim**
  - Investigation of industrial suitability
  - Exposure of influencing parameters
  - Tips for further laboratory tests

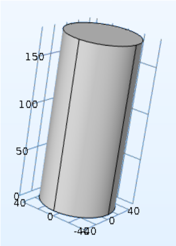
2. „Thermit“- exothermic Reaction

- What is "Thermit"?
  - Mixture (metal oxide + pure metal powder)
  - Redox series
- Thermit Reaction
  - $Fe_2O_3 + 2Al \rightarrow AL_2O_3 + 2Fe + \mathbf{Heat}$

[1]

3. Experimental Setup

1. HP / HT reactor: 200 bar, 300 ° C
2. Capsule
3. Tubing pipe
4. Sealing rings
5. Ceramic and steel plates
6. Thermo- and pressure sensors
7. Computer with LabVIEW



4. Modeling and simulation steps in COMSOL

1- space dimension

2- Geometry

3 Materials

4- physics

5- net

6- study

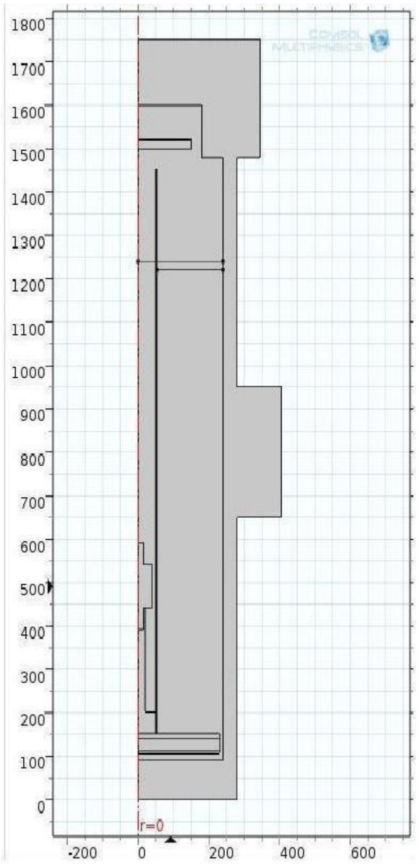
4.1 space dimension

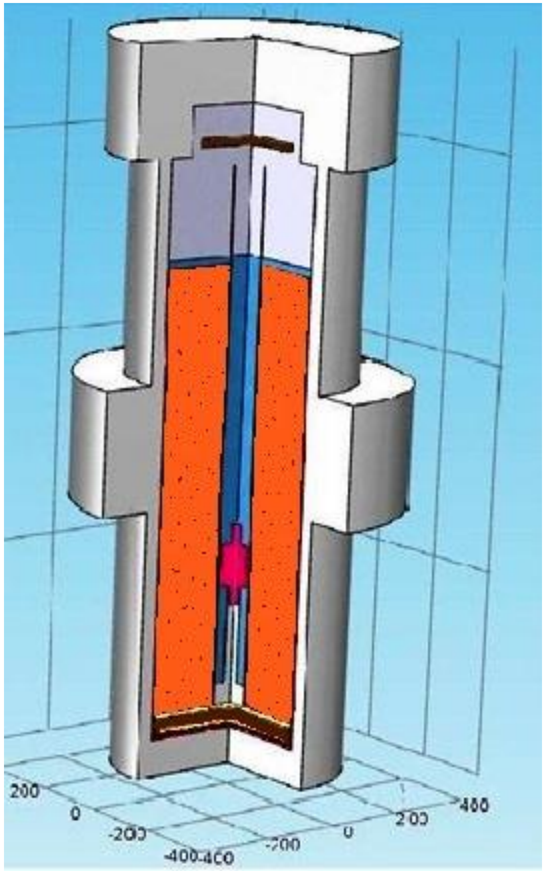
Symmetry of the reactor

- **2D rotationally symmetric**

4.2 geometry

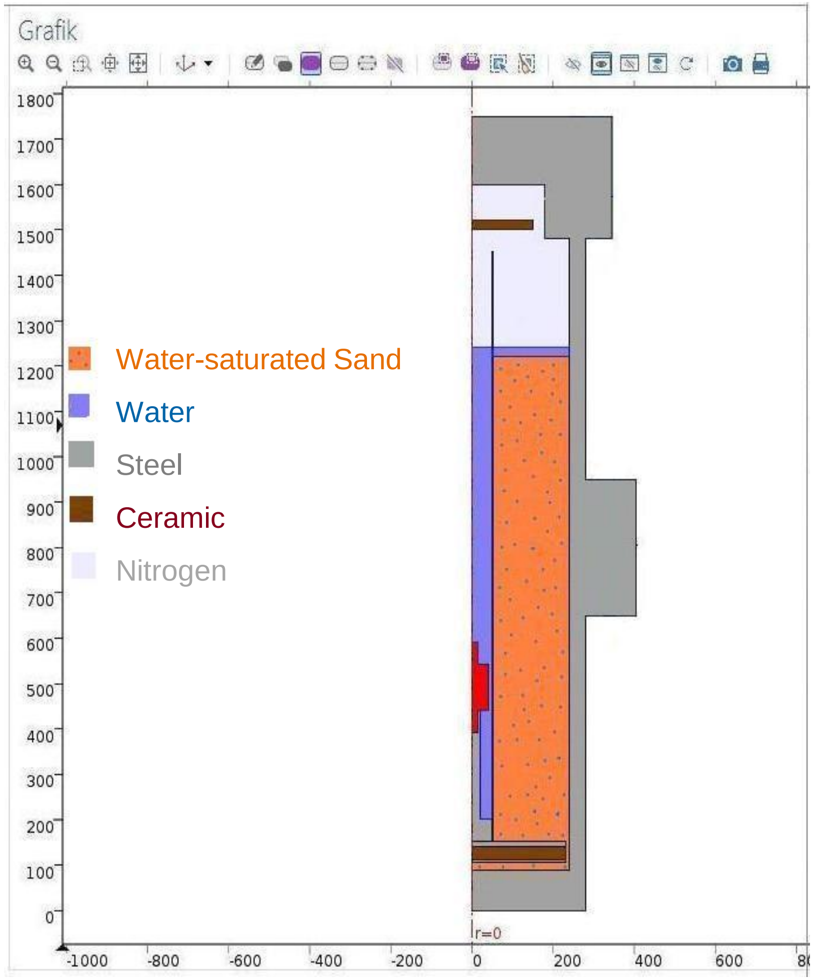
Different possibilities (done with COMSOL Multiphysics)





4.3 Materials

- Adding & connecting all materials with individual domains
- Adding materials properties



4.4 Physics

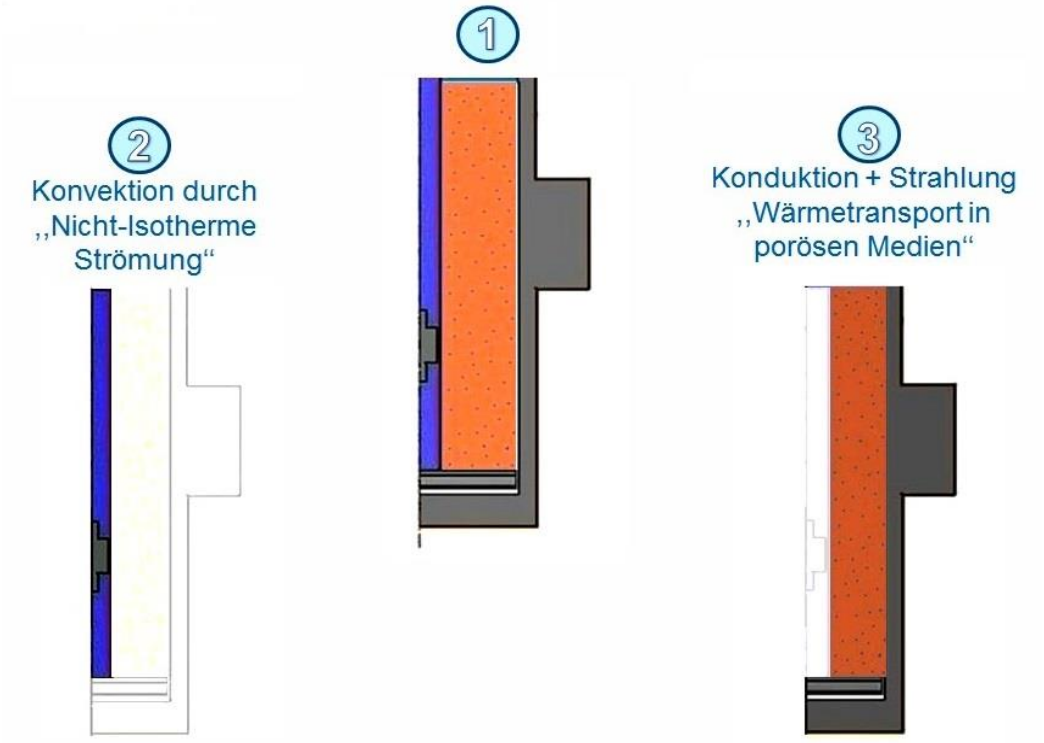
Adding & connecting all physical processes with individual domains

- Heat transport by convection
- Heat transport by conduction
- Heat transport by radiation ***X***
  - Surface-to-surface radiation (Between the capsule surface and the surface of the tube)
  - Surface-to-ambient radiation
- Phase change ***X***

4.4 Physics

Simplification and solving physical processes successively

- *Step1: Simplification*
- *Step 2: Convection "non-isothermal flow" (NIF)*
- *Step 3: Conduction "Heat transport in porous media" (HTPM)*



4.5 Net: User-defined net

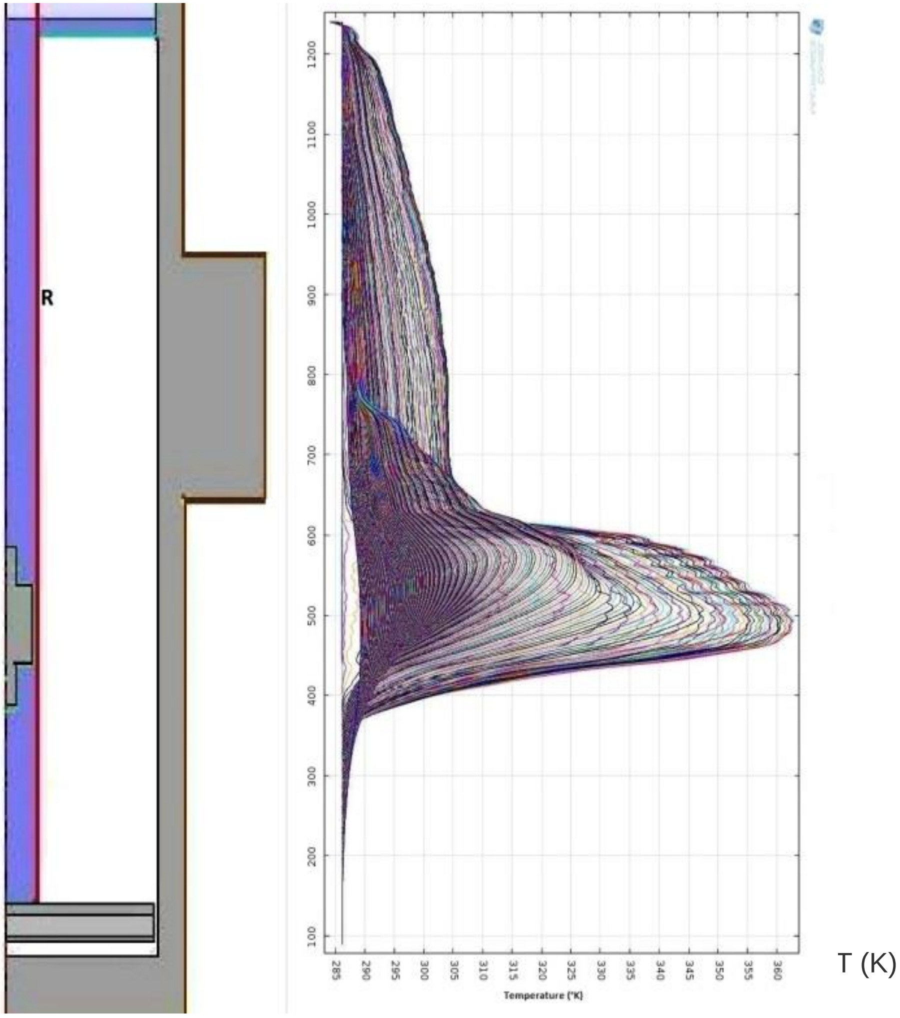
4.6 Study: time dependent

5. Results

Results of step 2

- Temperature distribution

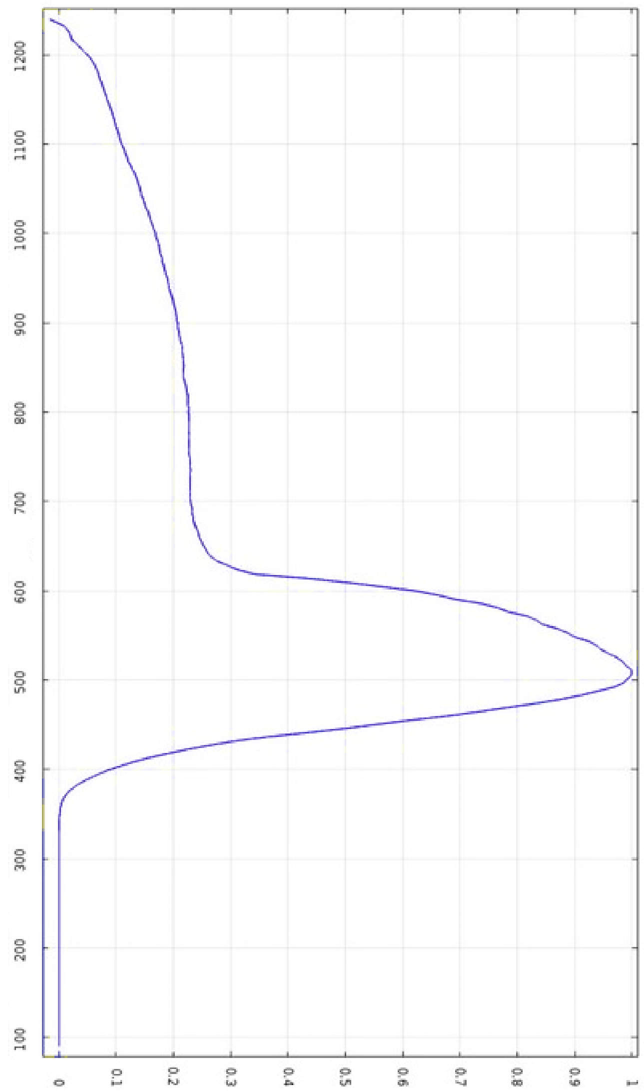
  on the edge R



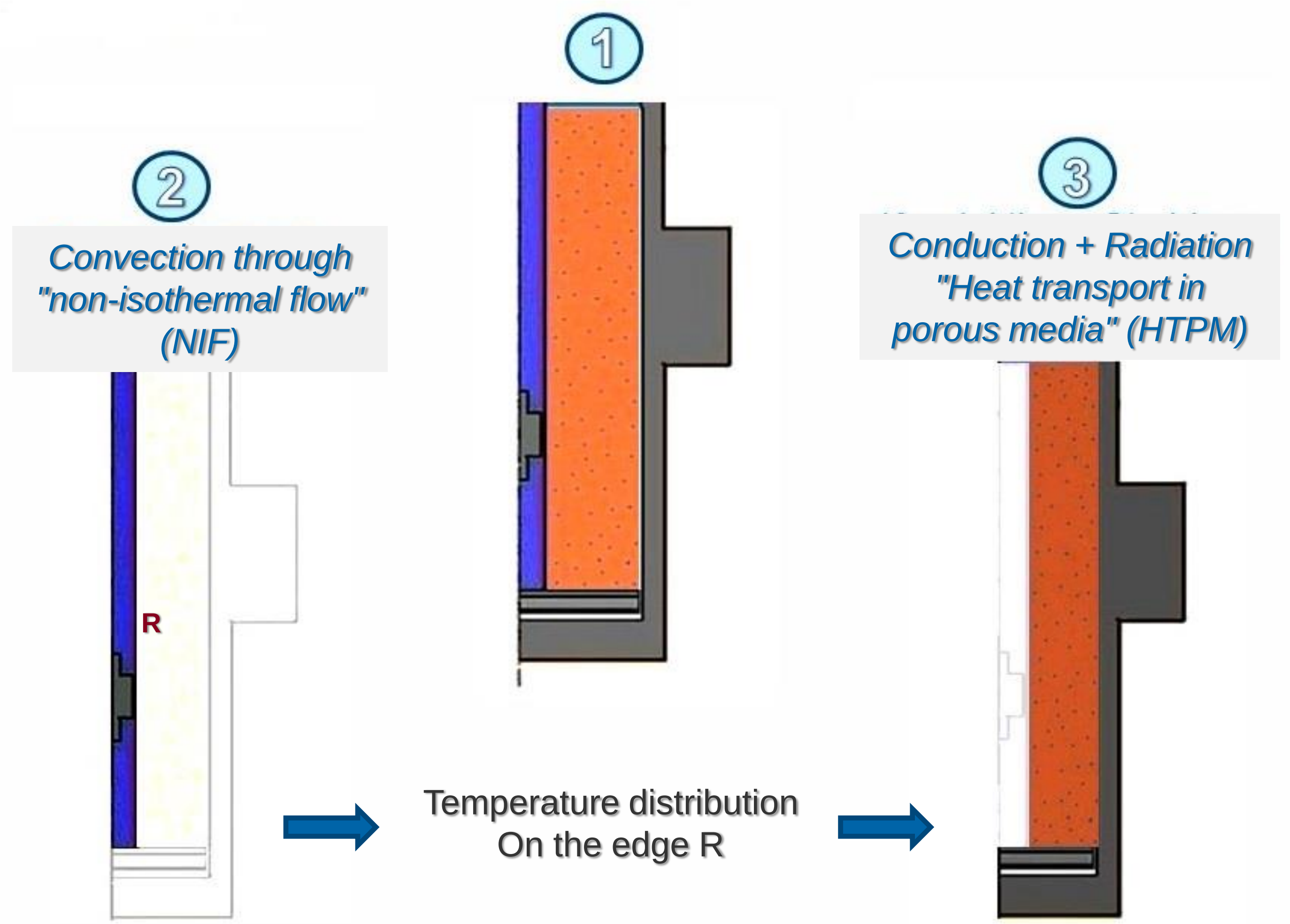
Temperature distribution on the edge R

5. Results

- Mean temperature distribution on edge R



5. Results



1
2
Convection through "non-isothermal flow" (NIF)
R
3
Conduction + Radiation "Heat transport in porous media" (HTPM)
Temperature distribution On the edge R

5. Results

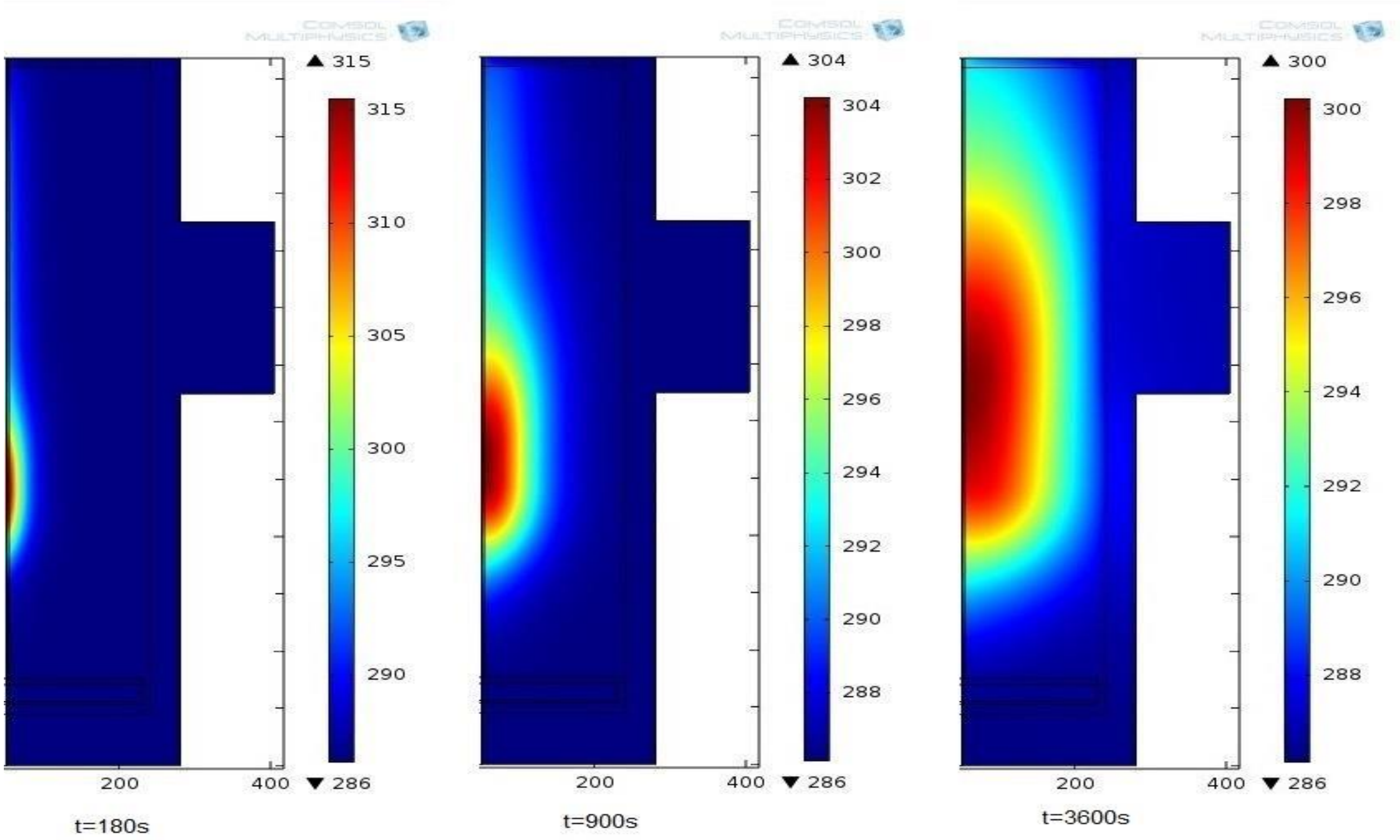


Figure 5. Temperature distribution in water - saturated sand at certain times

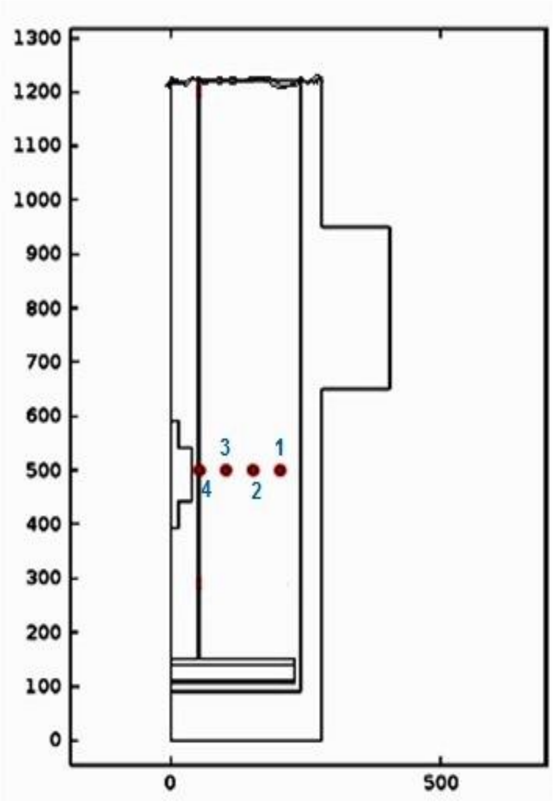
5. Results

Point	Distance from tubing (mm)	Distance from upper edge Bottom plate (mm)
1	150	410
2	100	410
3	50	410
4	0	410

Positions of the measuring points in the reactor

point	max. calculated temperature	max. measured temperature
T4	52.0	52.029
T3	13.740	12.098
T2	7.290	6.462
T1	3.350	4.454

a comparison between the maximum temperature difference obtained from the simulation and the measuring at each point

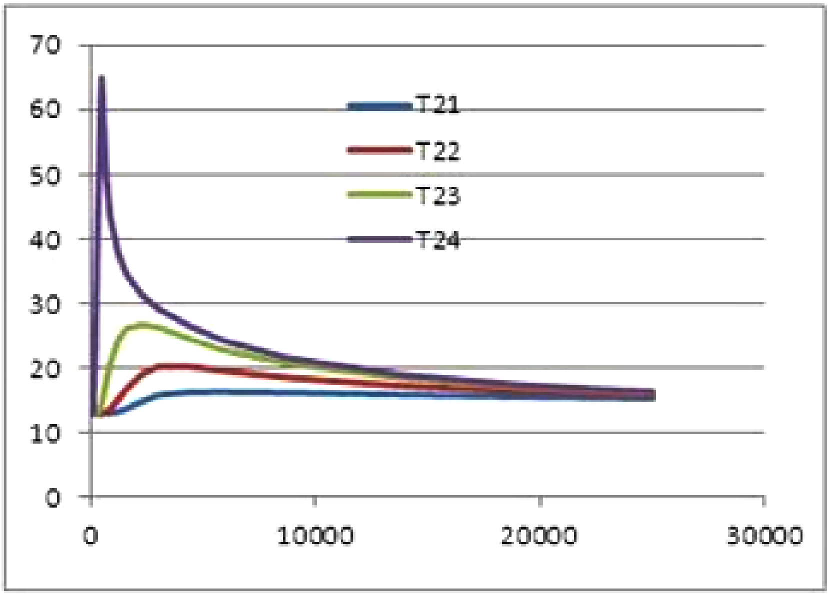


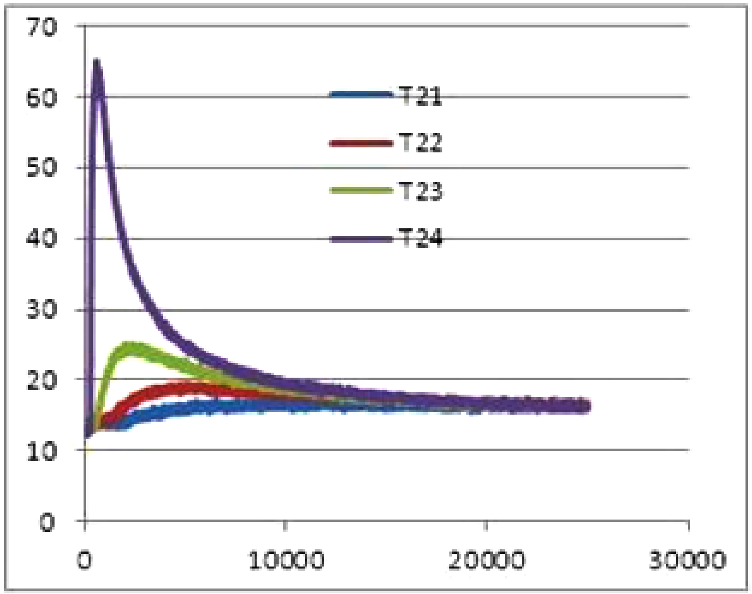
5. Results

Results of step 3

Temperature curves

T (°C)





time (S)

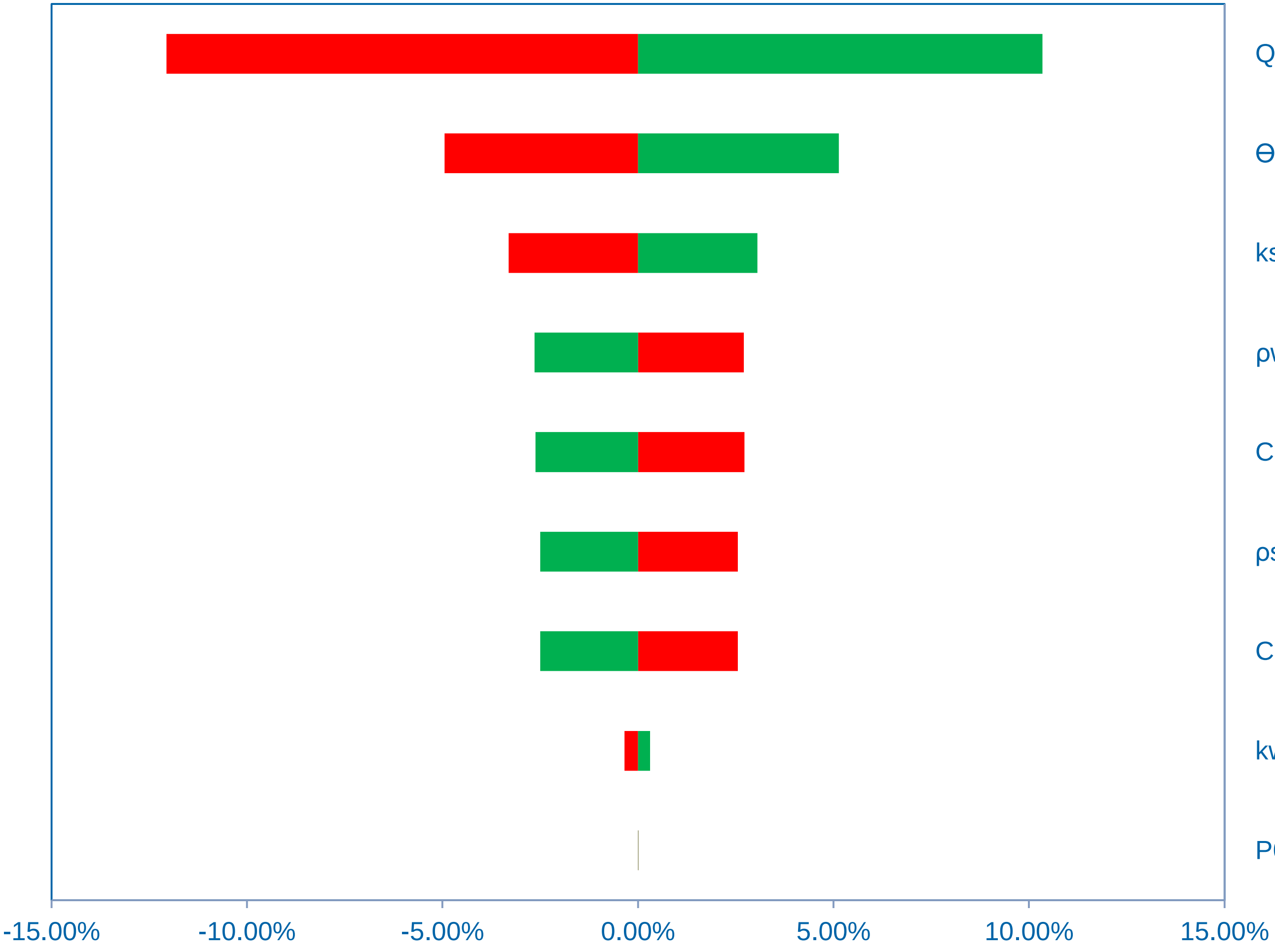
Calculated T.

Measured T.

5. Sensitivity analysis for heat transfer in porous media

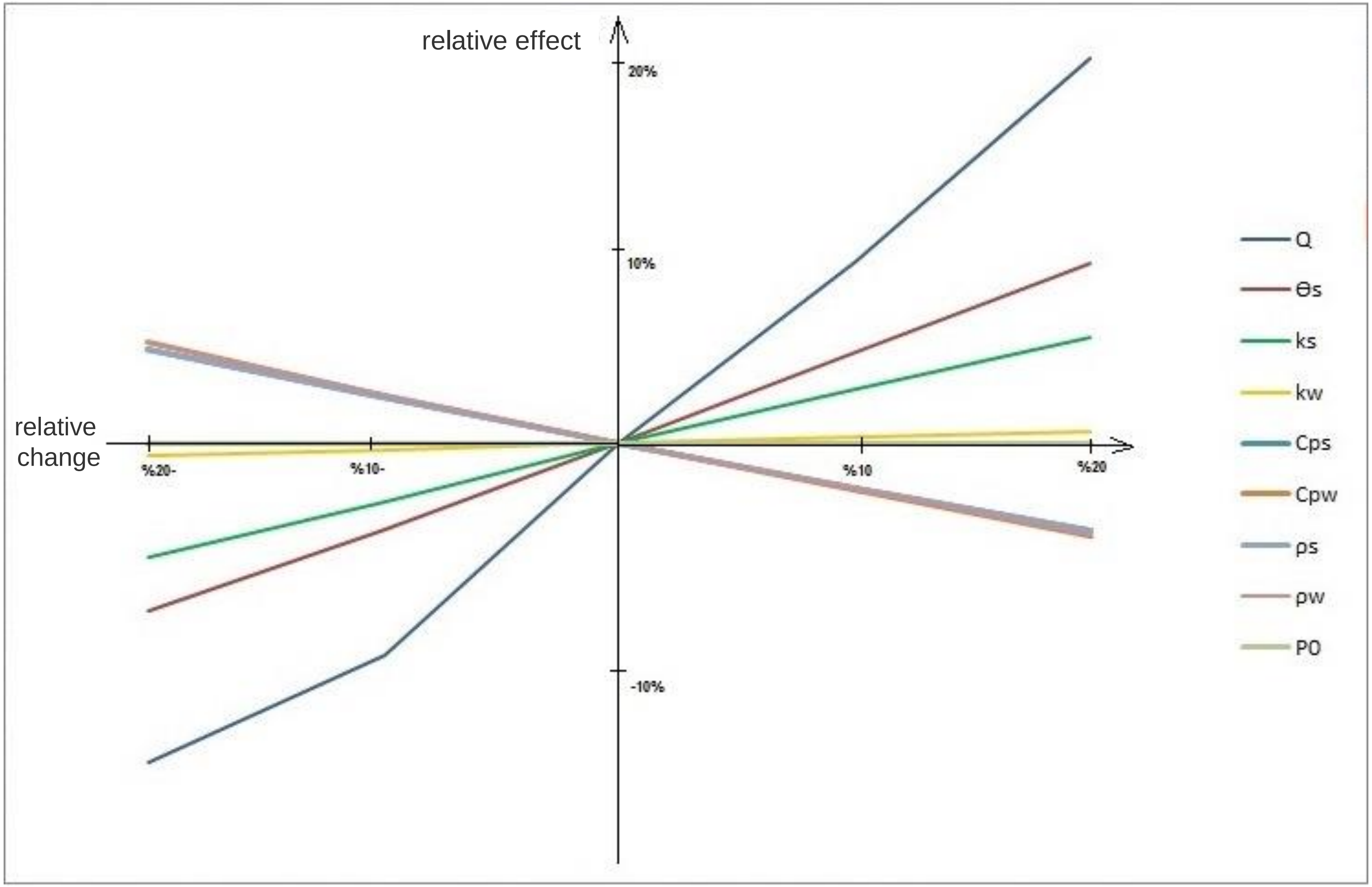
parameter	Temperature difference (T-T0) at any point (point 2)					Relative changes of the base value				
	-20%	-10%	base value	10%	20%	-20%	-10%	base value	10%	20%
Q	1.40715	1.5117	1.719	1.89689	2.094	-0.18141361	-0.12057592	0	0.10348458	0.218121
Ɵs	1.55558	1.6339	1.719	1.80734	1.8953	-0.0950669	-0.04949389	0	0.05139034	0.10253636
ks	1.6078	1.6621	1.719	1.77148	1.8224	-0.06468877	-0.03308319	0	0.03052938	0.06012798
kw	1.70728	1.7131	1.719	1.72432	1.7297	-0.00681792	-0.00342059	0	0.00309482	0.00621291
Cps	1.81127	1.7629	1.719	1.67602	1.6337	0.053676556	0.025549738	0	-0.02500291	-0.0496102
Cpw	1.81774	1.7658	1.719	1.67389	1.6292	0.057440372	0.0272484	0	-0.026242	-0.0522397
ρs	1.81127	1.7629	1.719	1.67602	1.6337	0.053676556	0.025549738	0	-0.02500291	-0.0496102
ρw	1.8174	1.7655	1.719	1.67354	1.6285	0.057242583	0.027056428	0	-0.02644561	-0.0526585
P_0	1.71909	1.7191	1.719	1.71909	1.7191	5.2356E-05	5.2356E-05	0	5.2356E-05	5.2356E-05

▪ Tornado chart



Q	**Heat quantity**
Ɵs	**Volume fraction of the sand**
ks	**Thermal conductivity of sand**
ρw	**Density of water**
Cpw	**Heat capacity of the water**
ρs	**Density of sand**
Cps	**Heat capacity of the sand**
kw	**Thermal conductivity of water**
P0	**pressure**

▪ Spider chart



6. Summary

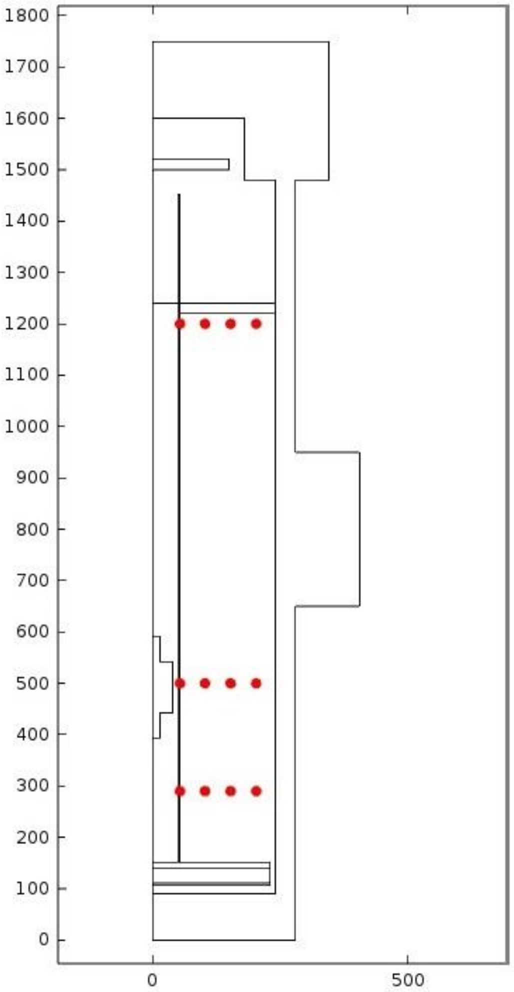
- For a thermal treatment of the near borehole area a heat transfer simulation was performed with COMSOL Multiphysics for a HT/HP reactor
- It was necessary to take into account both convection and conduction heat trensfer
- The simulation results showed a good match in comparison to the actual measured temperatures
- A corresponding sensitivity analysis was carried out for further laboratory tests

Thanks a lot

[1] Lothar Fendrich (Hrsg.): *Handbuch Eisenbahninfrastruktur.* Band 10, Springer Berlin 2006, ISBN 3-540-29581-X, 317, 318

Ergebnisse des Fallbeispiels 2 (große Kapsel,30bar)

Punkt	max. berechnete Temperatur	max. gemessene Temperatur
T32	3.888247	7.659235
T33	6.06	7.596876
T34	7.06	8.692579
T21	3.35	4.45377
T22	7.29	6.462231
T23	13.74029	12.09785
T24	52	52.02919
T11	1.675822	3.217616
T12	2.10063	3.018485
T13	3.330063	5.804523
T14	4.675826	4.935552

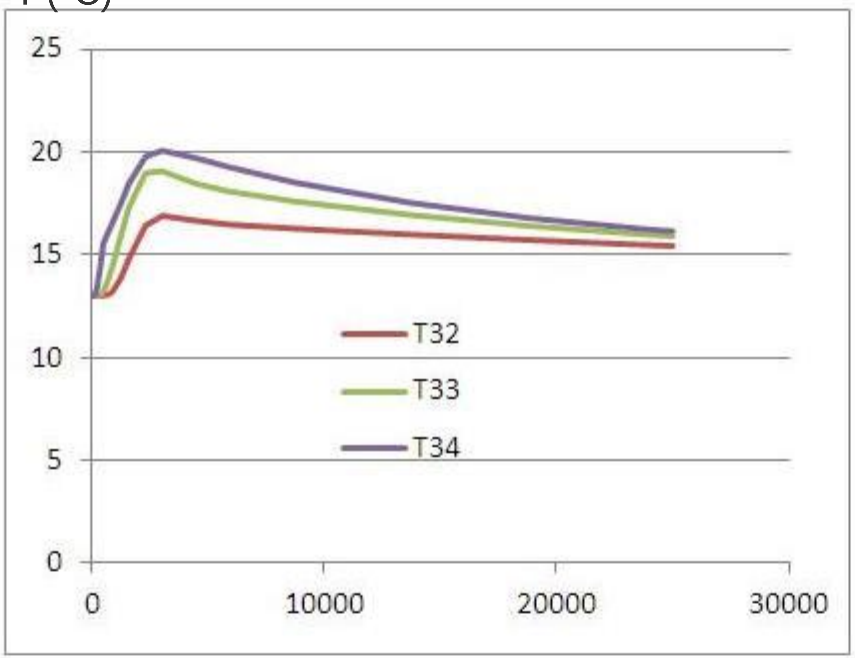


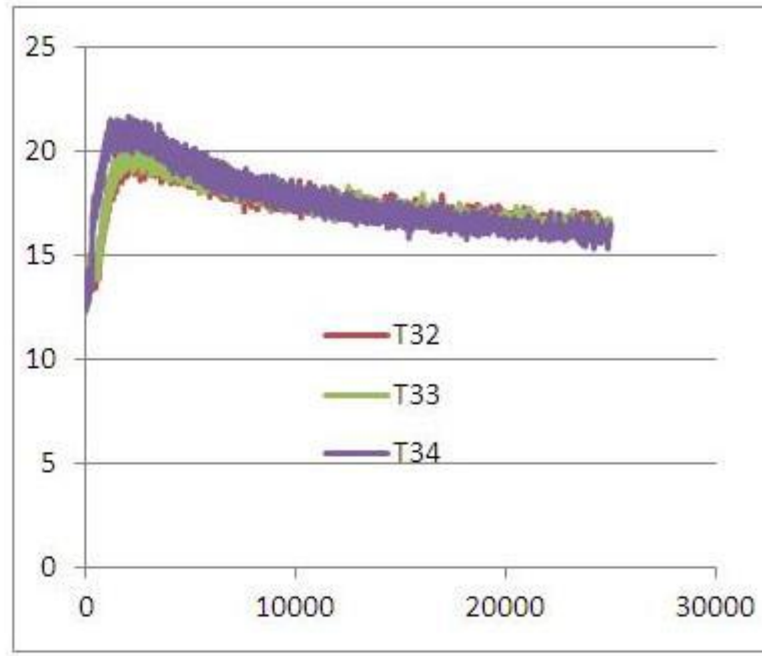
Ergebnisse des Fallbeispiels 2 (große Kapsel,30bar)

2- Temperaturkurven

- H3=1110 mm

T (°C)





t (S)

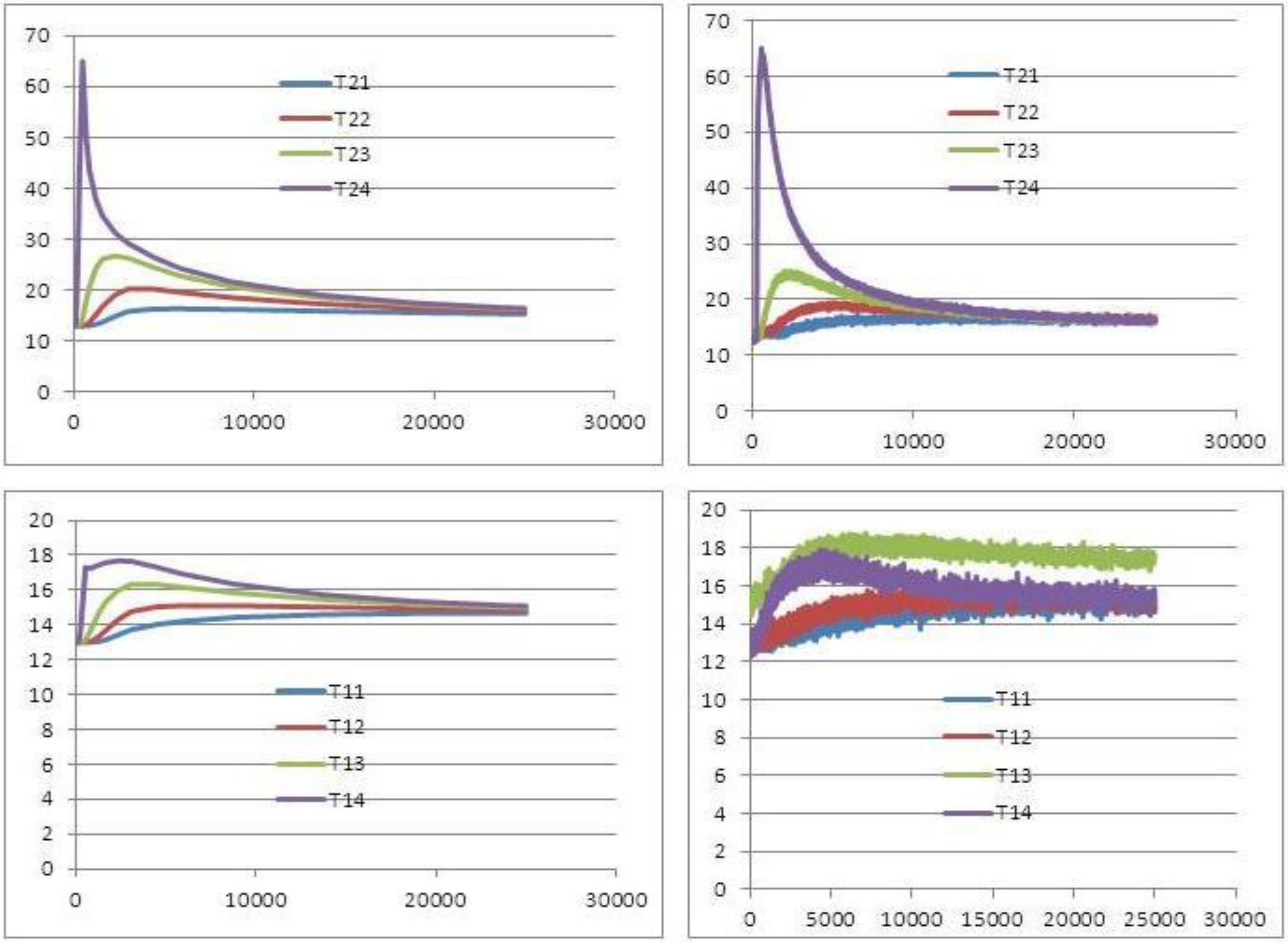
Berechnete T.

Gemessene T.

4 Ergebnisse

- Temperaturkurven (H1= 200 mm, H2= 410 mm)

T (°C)



t (S)

t (S)

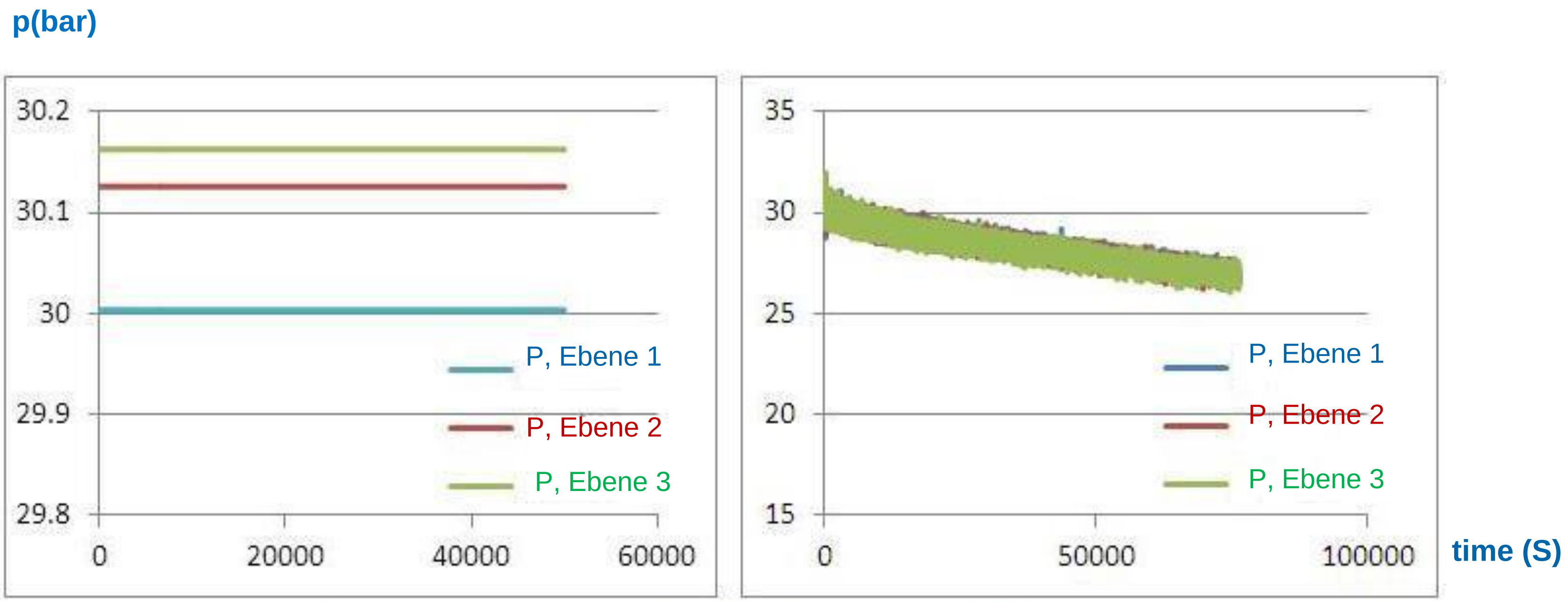
Berechnete T.

Gemessene T.

5. Results

Results of step 3

Pressure curves



Calculated p. Measured p.

2.2 COMSOL-Multiphysics

- Why COMSOL? Range of Optionen & Parallel Solutions