# Analysis of the temperature, the pressure and the vapour density in a VPS chamber to optimize the conditions for soldering

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# VAPOUR PHASE SOLDERING

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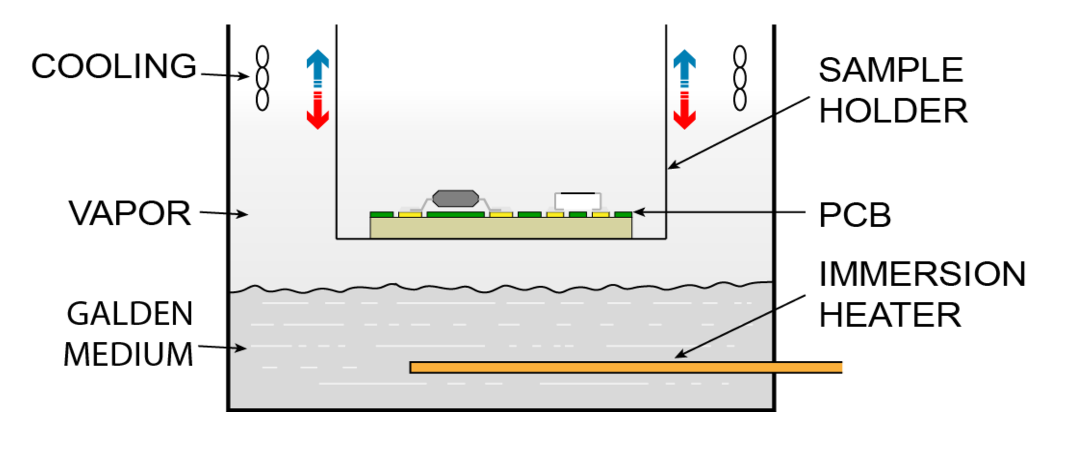
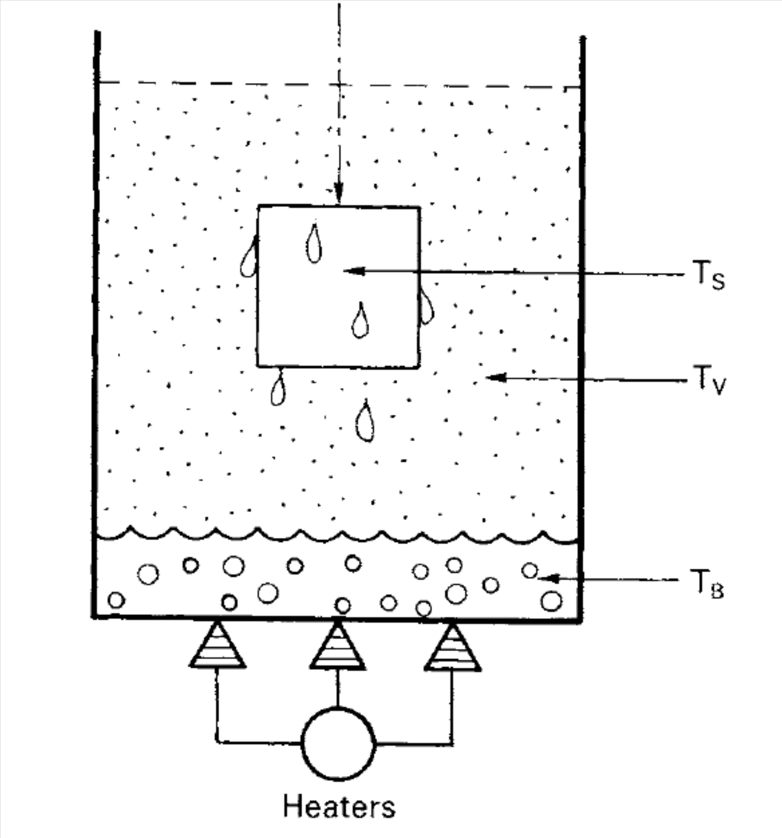



BATCH TYPE VPS OVEN

- Heating PFPE fluid to obtain saturated vapour (GALDEN)
- Inert chemical, not harmful
- Immersion of ambient temperature PCB into the vapour
- CONDENSATION – heat transfer


[1] R. C. Pfahl; H. H. Ammann. Method for Soldering, Fusing or Bracing, *US Patent 3,866,307*; Feb. 18, 1975.
[2] Wolfgang Leider, "Dampfphasenlöten: Grundlagen und praktische Anwendung" Leuze, E G; 2002.
[3] H. Leicht; A. Thumm. Today’s Vapor Phase Soldering - An Optimized Reflow Technology for Lead Free Soldering, *SMTAI Conference Proceedings*, Orlando, 17-21 August 2008.

# BASICS OF CONDENSATION SOLDERING




## The vapour is saturated

$T_B = T_V$

$T_S < T_V$

$T_B$ – the boling point of the fluid (***B***oiling)
$T_V$ – temperature of the vapour
$T_S$ – solderable sample

# ENERGY OF CONDESATION

$$Q = m \cdot L$$

Where:

- Q is the amount of energy released during the phase change [J], this time **CONDENSATION**
- m is the mass of the condensed liquid [kg],
- L is the specific latent heat for the liquid [J/kg]

# HEAT TRANSFER

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$$\Delta Q = \alpha \cdot A \cdot \Delta T = \alpha \cdot A \cdot (T_F - T_S)$$

***α*** = 230-250
for Galden
(30-120 for gases)

- Δ Q is the heat input [W],
- ***α*** is the heat transfer coefficient [W/(m2K)],
- A is the heat transfer surface area [m2],
- Δ T is the difference in temperature between the solid surface and surrounding fluid *film*[K].

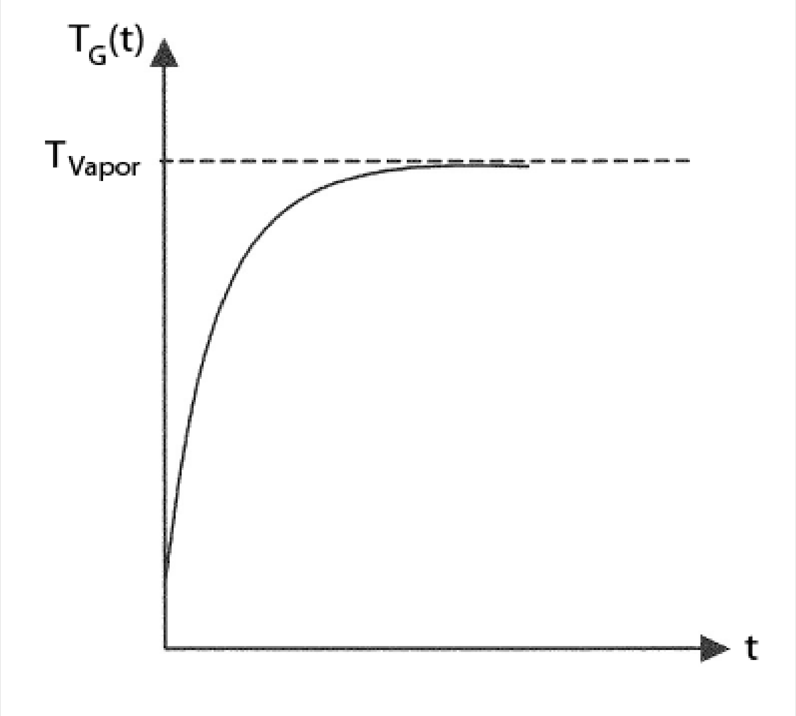
# TEMP. CHARACTERISTIC OF A HEATED SAMPLE

$$\ln\left(\frac{T_{vapor} - T_G}{T_{vapor} - T_{G,0}}\right) = -\frac{\alpha \cdot A}{m \cdot c} \cdot t$$

$$T_G(t) = T_{Vapor} - (ae^{-t} + b)$$

- $T_{Vapor}$ – vapour temperature
- $T_G$ – temperature of the sample
- $T_{G,0}$ – temp. of the sample at 0 time

- t – time
- α – heat transfer coeff.
- m – mass of sample
- c – specific heat capacity of the sample
- A – full area of the sample
- a,b – process related factors




Logarithmic plot

Wolfgang Leider: Dampfphasenlöten

# GALDEN FLUID

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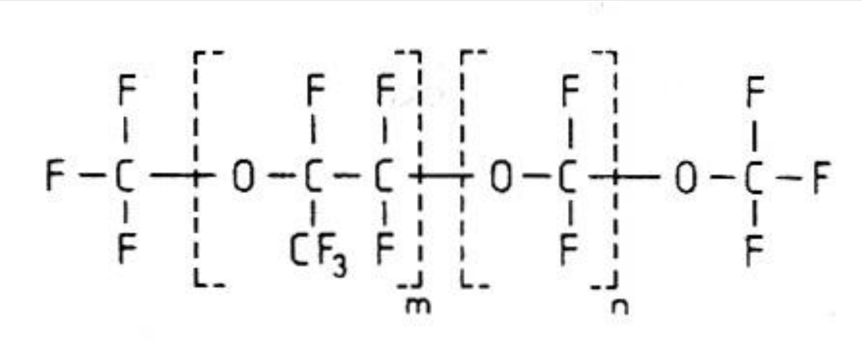
- Novel material – providing solution for CFC problems – Zero ozone depletion (not harmful for the ozone layer)

- Perfluoropolyether;
- Inert (no reactions);
- Good dielectric;
- Good wetting properties;
- Available with different boiling points;



Ether chain with strong C-F bonds m/n~50

$CF_3 - (\underset{\displaystyle CF_3}{OCFCF_2})_n - (OCF_2)_m - OCF_3$

# MOTIVATION OF WORK

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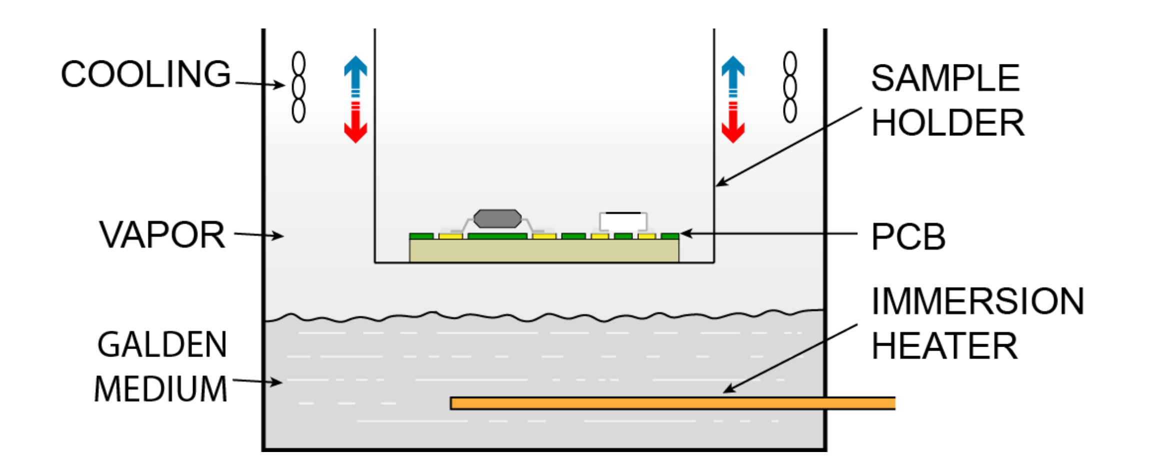
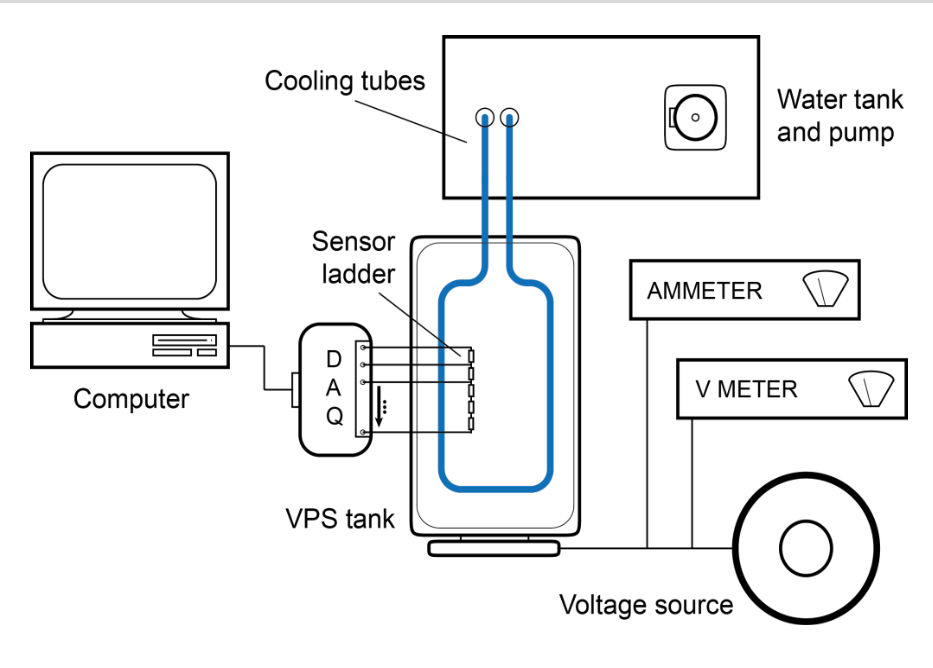
- Alternative method for reflow soldering in Electronics Technology
- Absence of thorough scientific discussion in literature:



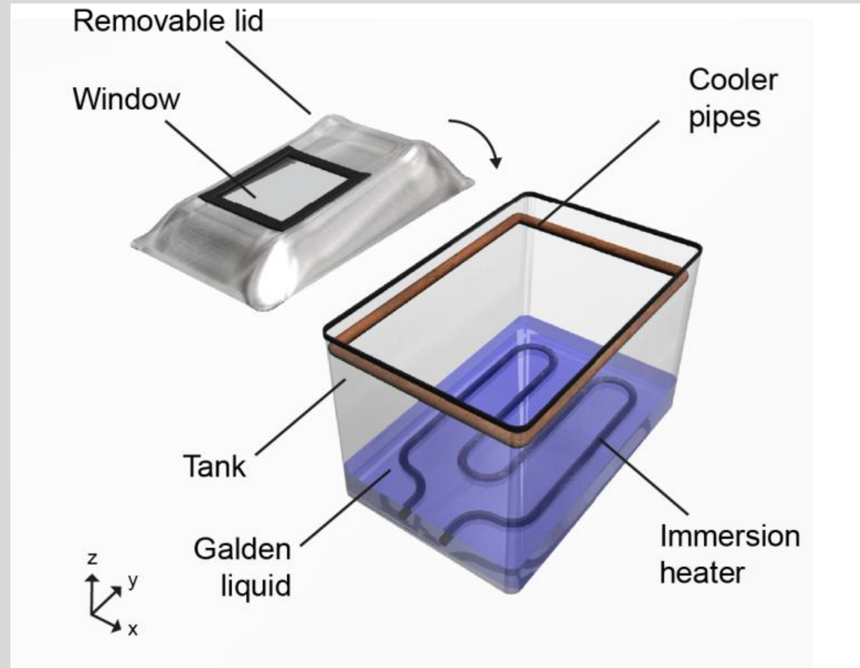

-> Temperature relations?
-> Condensation processes?
-> Identification of the Vapour
-> Solder joints?

- Condensation heat transfer is different from conventional reflow (IR, convection)
- For identification and full process control, novel measuring methods are needed
- Complex measurements, interpolated data
- Simulation – to investigate the key parameter relations inside the oven

# Experimental Oven ETT




Simplified Block Diagram




3D illustration of the oven

Ideal for modeling and simulation

# TEMPERATURE MEASUREMENTS

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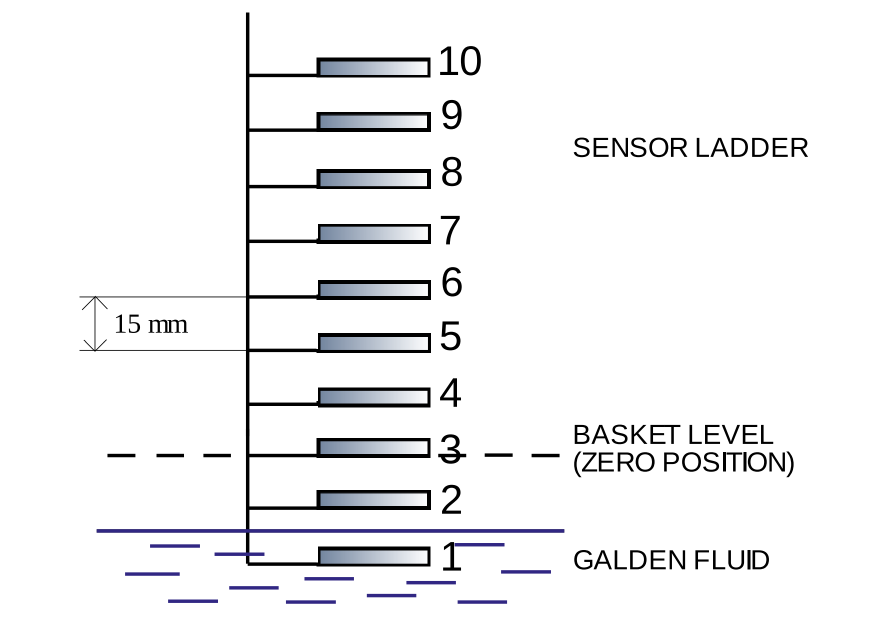


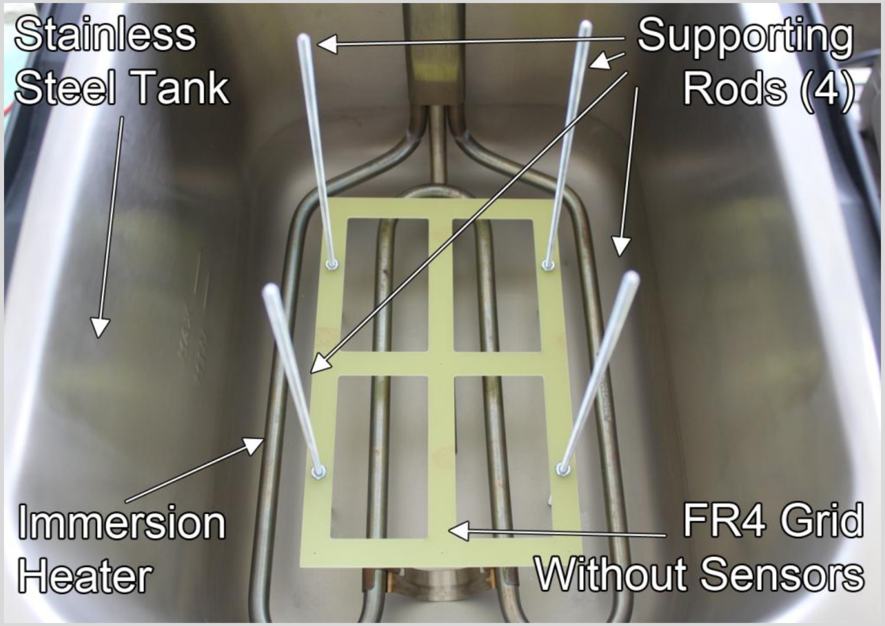


1D thermal measurements (Z)

2D thermal measurements (X,Y)

Pt500 sensor ladder

K-type thermocouple grid + interpolation

# TEMPERATURE MEASUREMENTS

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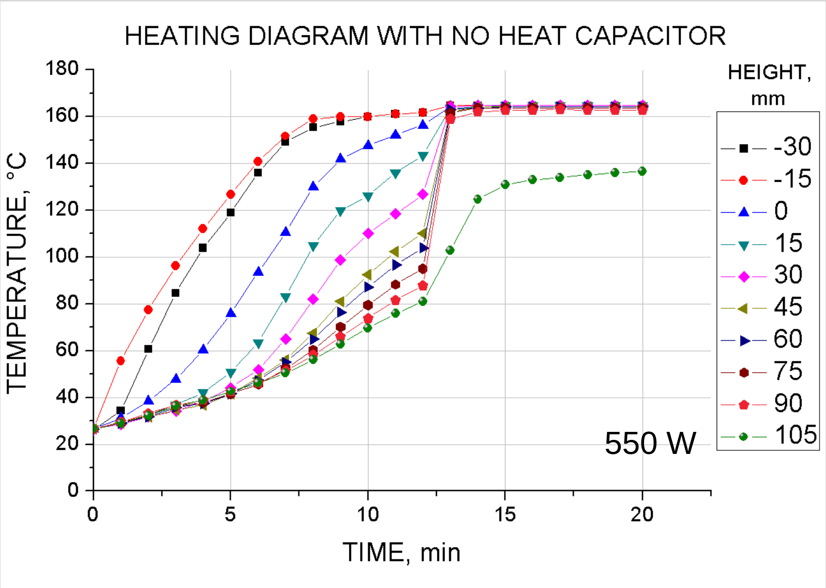


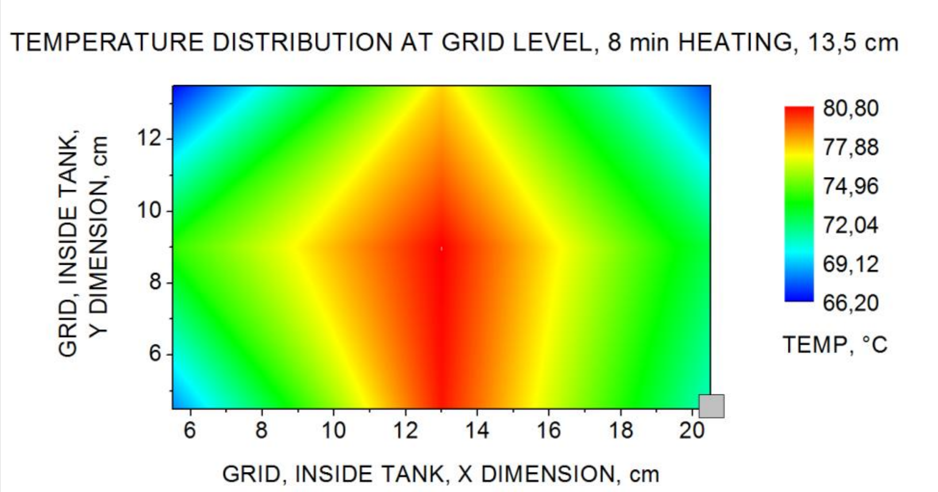


1D thermal measurements (Z)

2D thermal measurements (X,Y)

Pt500 sensor ladder

K-type thermocouple grid + interpolation

# 3D THERMAL VISUALIZATION

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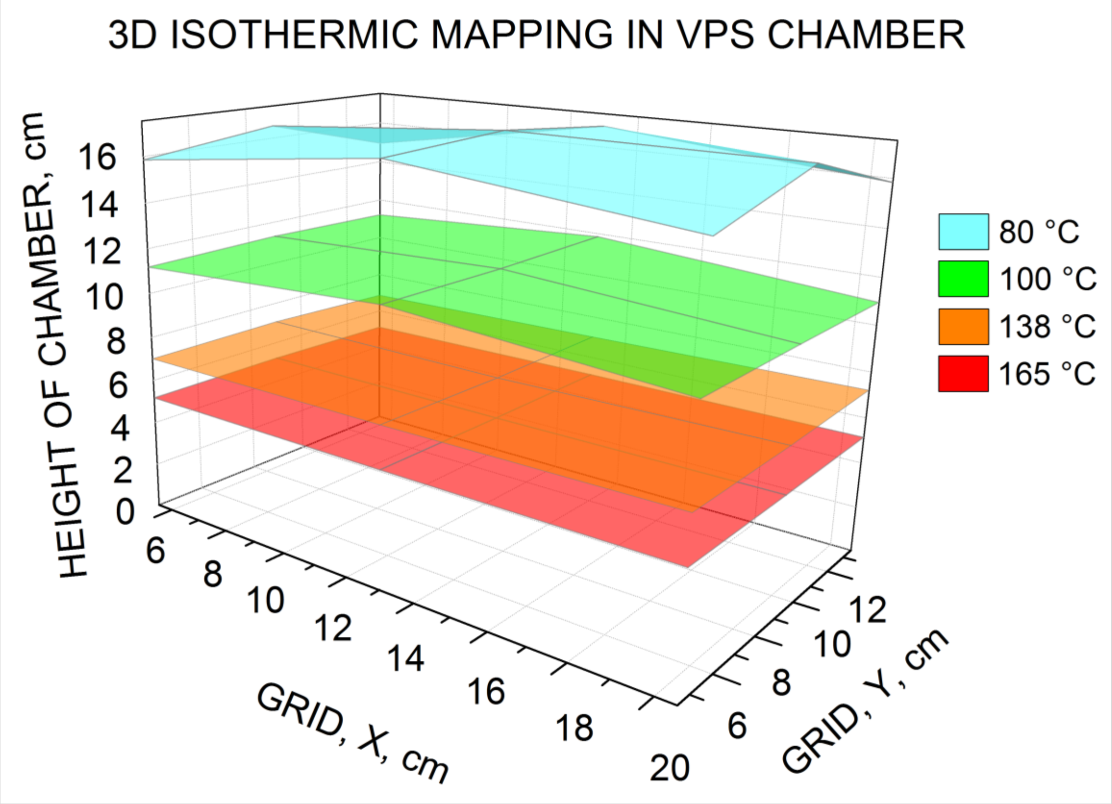


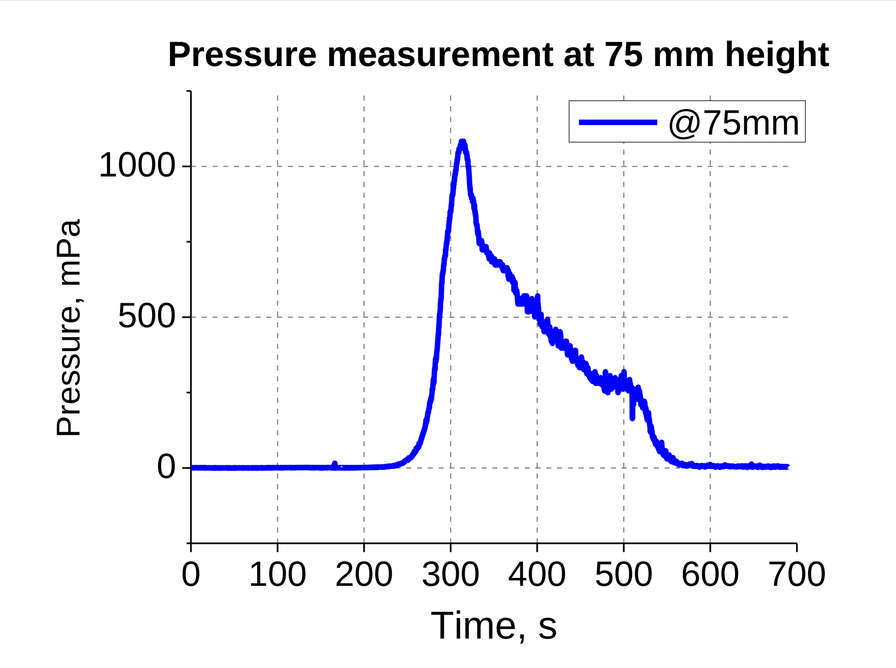

- With interpolation
- Setting the same parameters for each measurement with the 2D grid
- Data shows asymmetries,
- The measurements have limitations, with the increase of sensors additional thermal capacitances are added to the process zone

↓

SIMULATION!

# MEASURING THE PRESSURE RELATIONS


- Dynamic diff. Sensor
- 0.05 Pa resolution
-To measure pressure change
- Measuring hoses applied to the process zone




- Initial differential pressure result at a fix position (XYZ) in the oven and ambient space outside

# PRESSURE VS TEMPERATURE?

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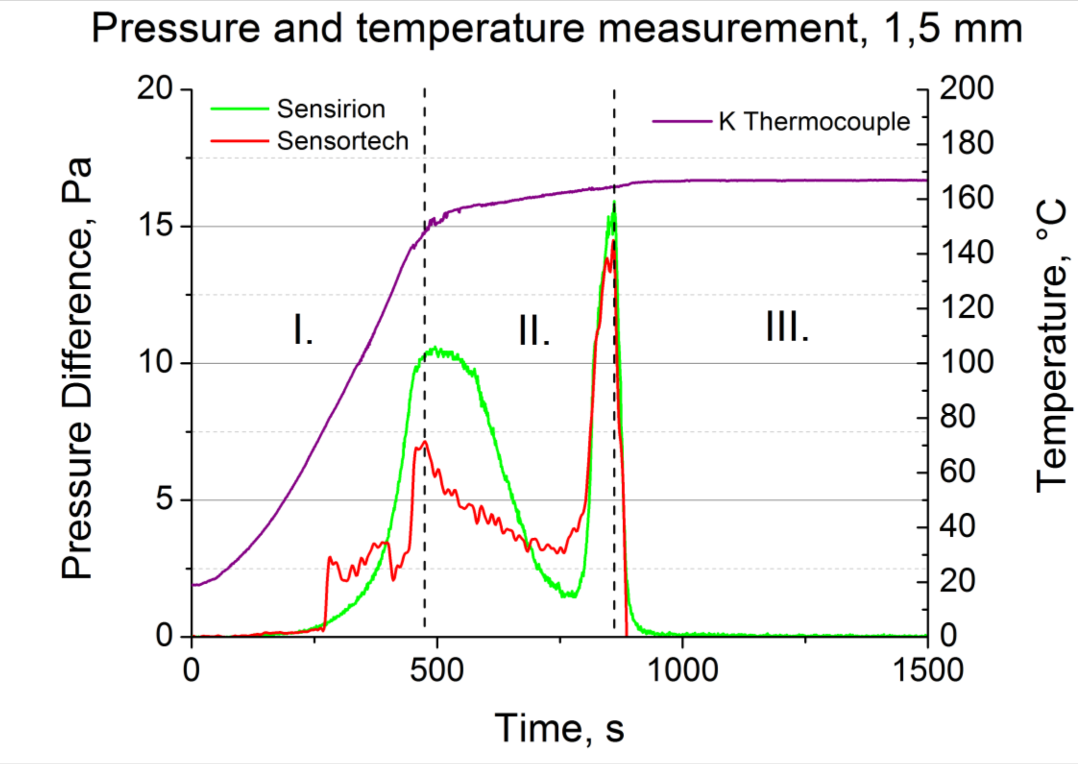
- Different sensors were applied

- Sensirion / Sensortech

- Not proper absolute pressure measurements

- Precise dynamic pressure measurements

An initial heating up period reveals that pressure is indicating saturated vapour more precisely

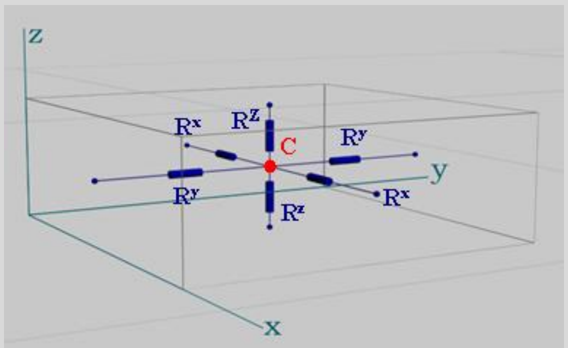



-Pressure measurements compared with the temperature measurement

# PREPARING FOR THE SIMULATION



- Finite difference method (FTCS)



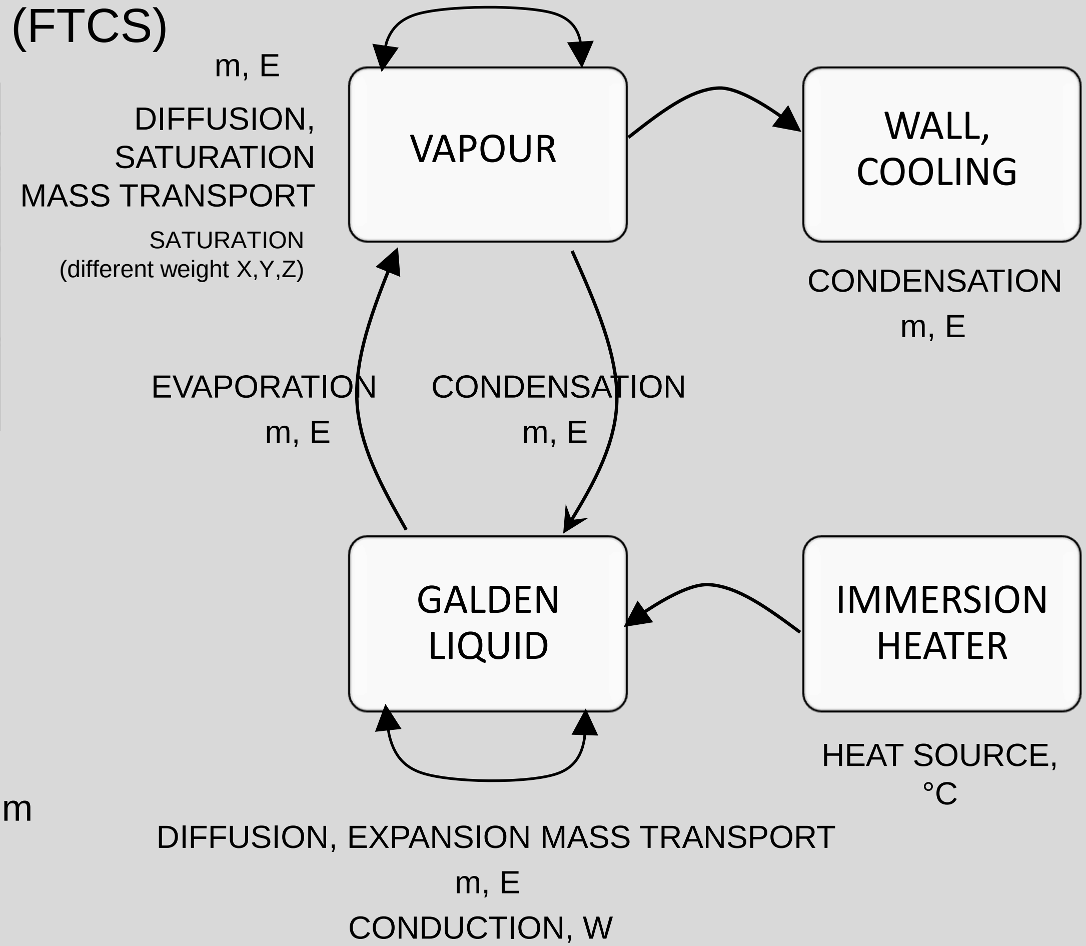

- Thermal nodes (Whalley model)

-Total sum of ~15.000 cells

-Cell sizes: 10,10,10 mm

-Geometry size:
(X;Y;Z) ->(180; 280; 170) , mm - > m

- Measurements for verification



# GEOMETRY

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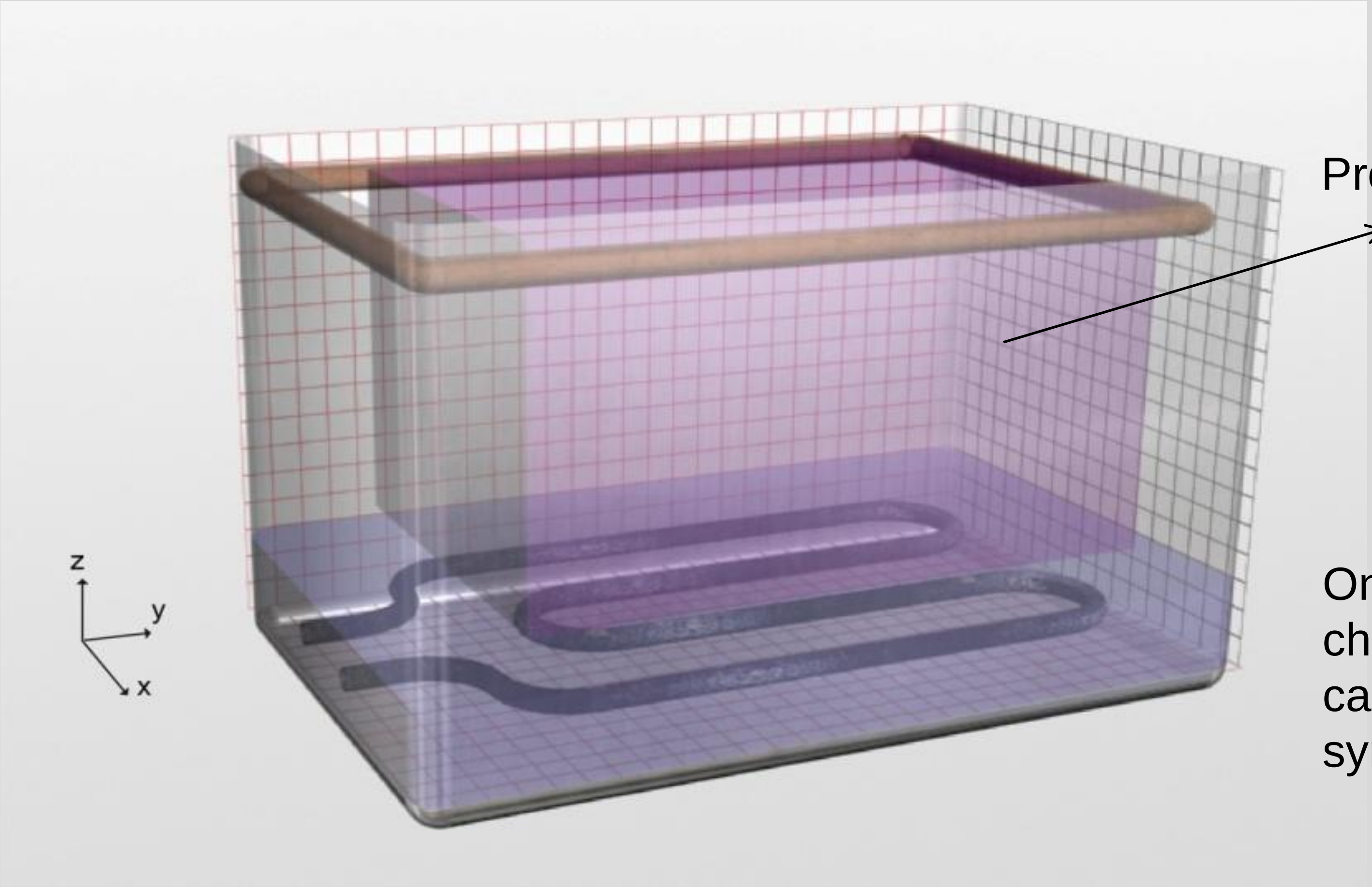


Processing zone

Only half of the chamber is calculated due to symmetry to Y axis!

# MEASUREMENTS FOR VERIFICATION

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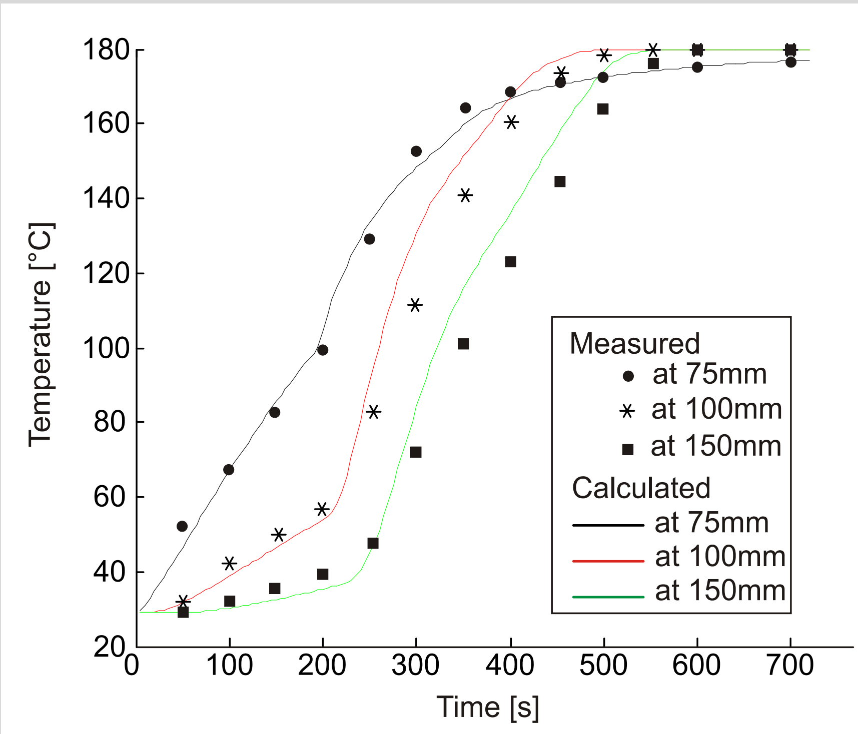


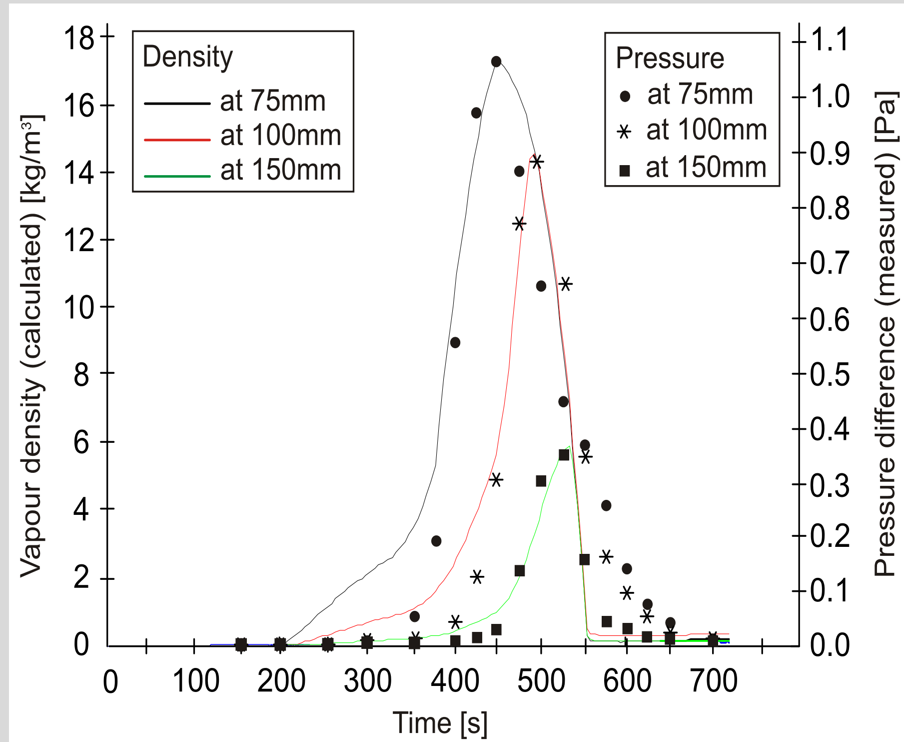


- Calculated values compared to measurement values

- Comparing vapour pressure difference (measured) and vapour density (calculated) – same characteristic

# SIMULATION RESULTS – TEMP.

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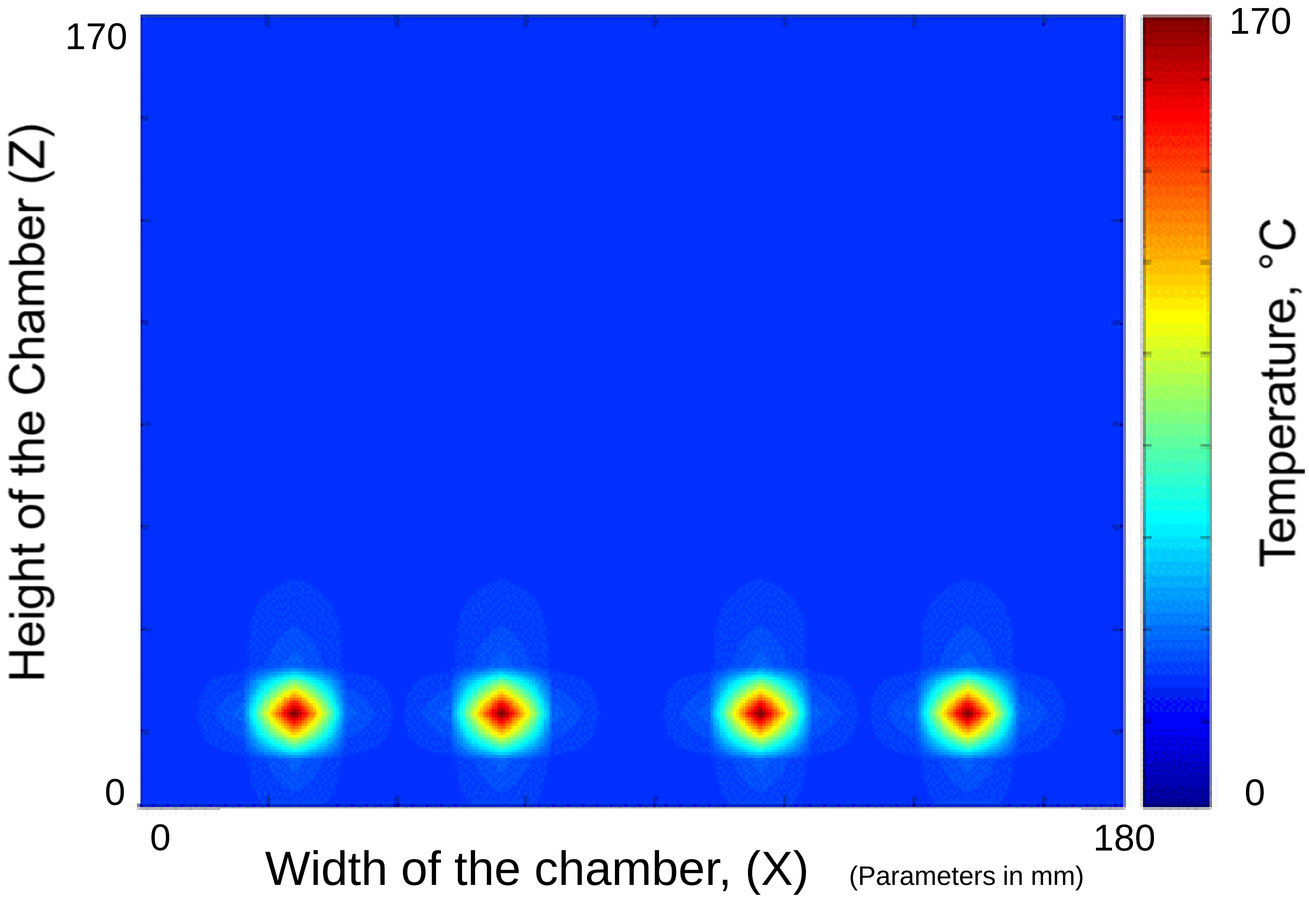
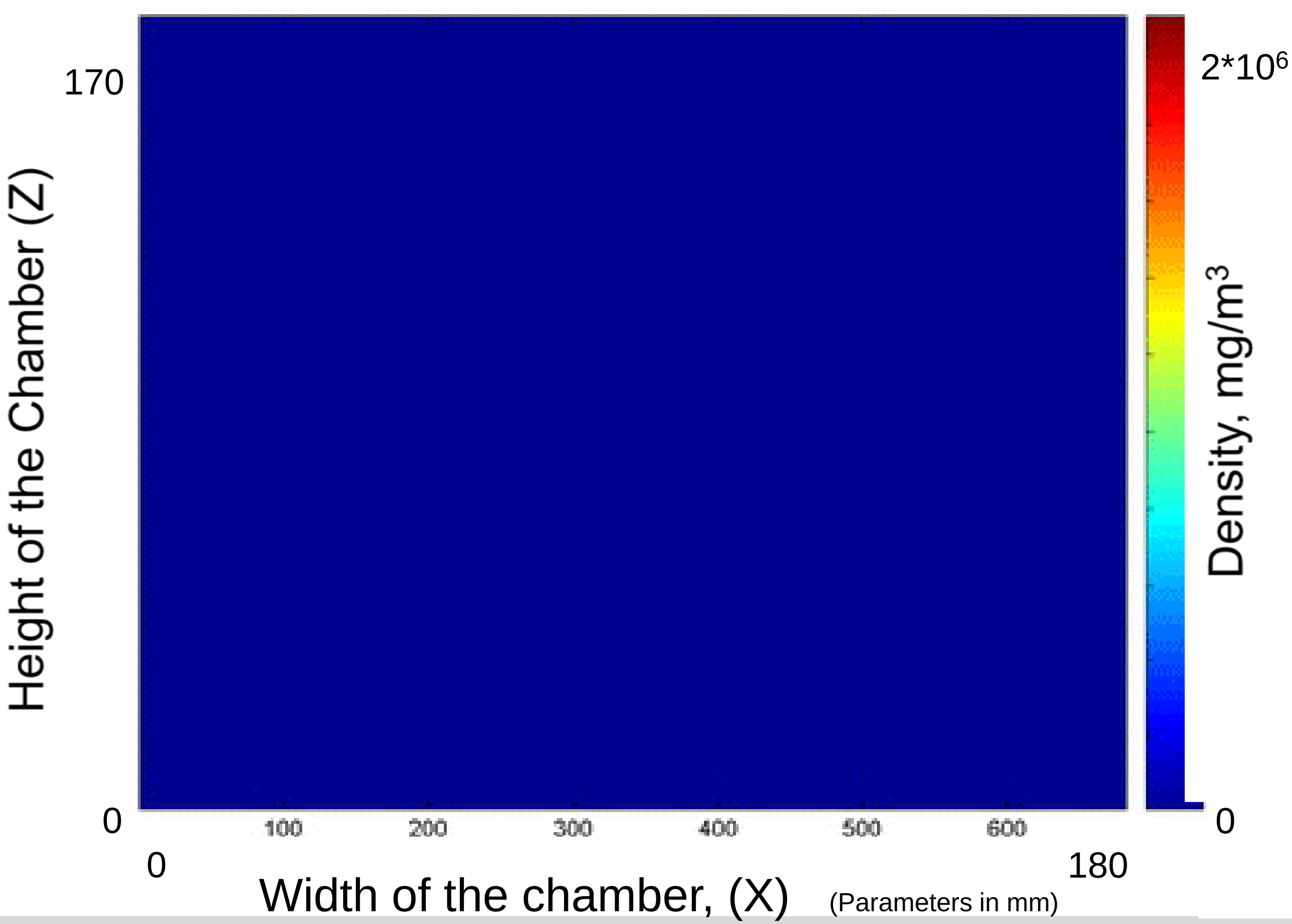
12 minutes



# SIMULATION RESULTS – SATURATION

12 minutes



# OPTIMAL PROCESS ZONE

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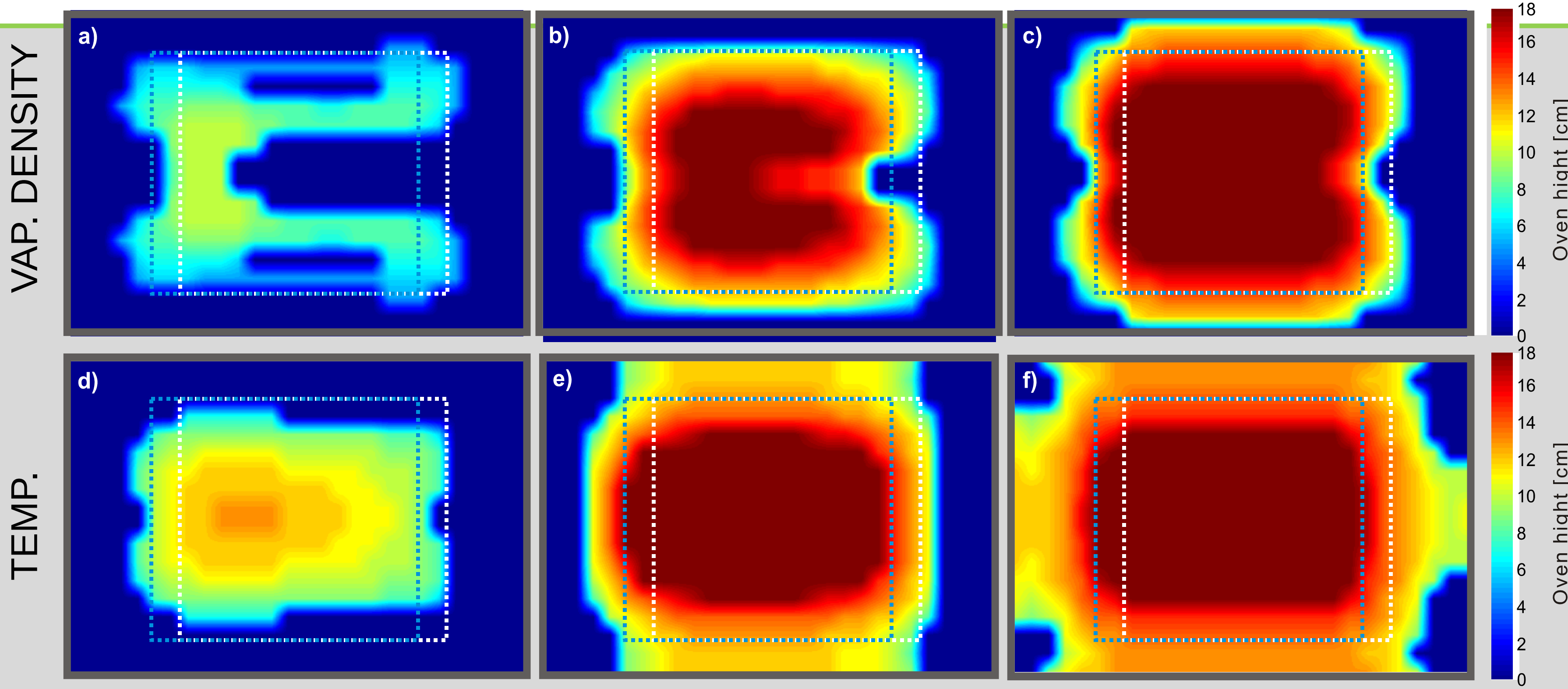


SATURATION shells at 8, 10 and 12 minutes
the parameter is the oven height

The blue/white rectangles -> optimal zone borders

<u>SATURATION:</u>
-VAP: 20 kg/m3
-TEMP.: 180 °C

# CONCLUSIONS

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- Successful measurements -> succesful verification of the simulation method
- The simulation method can define the optimal process zone inside the VPS oven
- Optimal process points to optimal control and optimal solder joints for future applications
- Future: simulation of immersed sample heating