UNIVERSITY OF CHEMISTRY AND TECHNOLOGY PRAGUE
Faculty of Chemical Engineering
Department of Chemical Engineering

Diverse Complexity of Pyrolysis Model Settings for RCT in FDS

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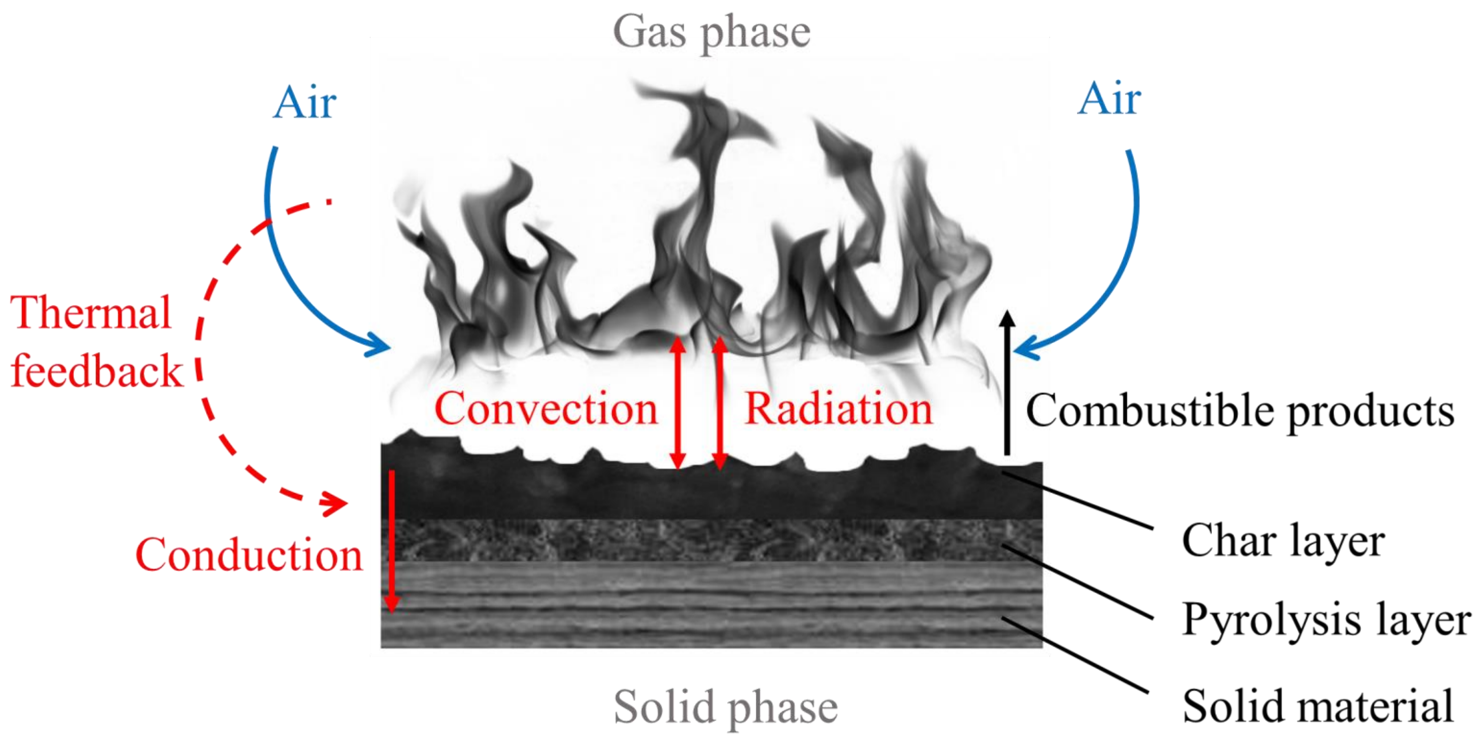
Pyrolysis

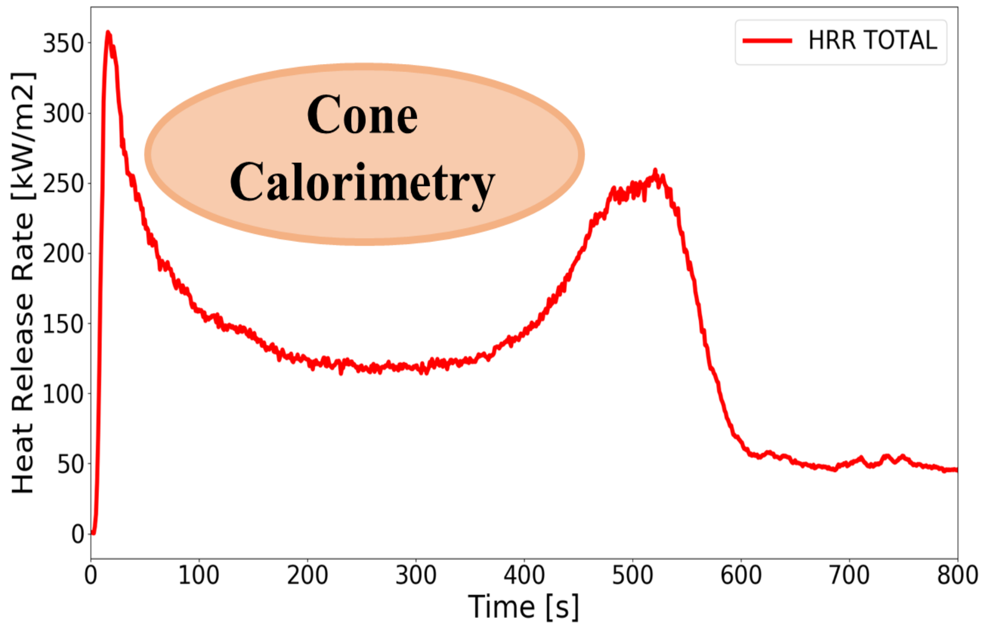


- Gaseous phase influence solid phase and vice versa
- How fast is gasification? $\dot{m}$ (mass loss rate, MLR)
- FDS (Fire Dynamics Simulator)
- Different approaches (variously complex), **2** main

Fire Consequence Modeling

- HRR (Heat release rate) - $\dot{q}''$
- Heat of combustion - ΔH_C

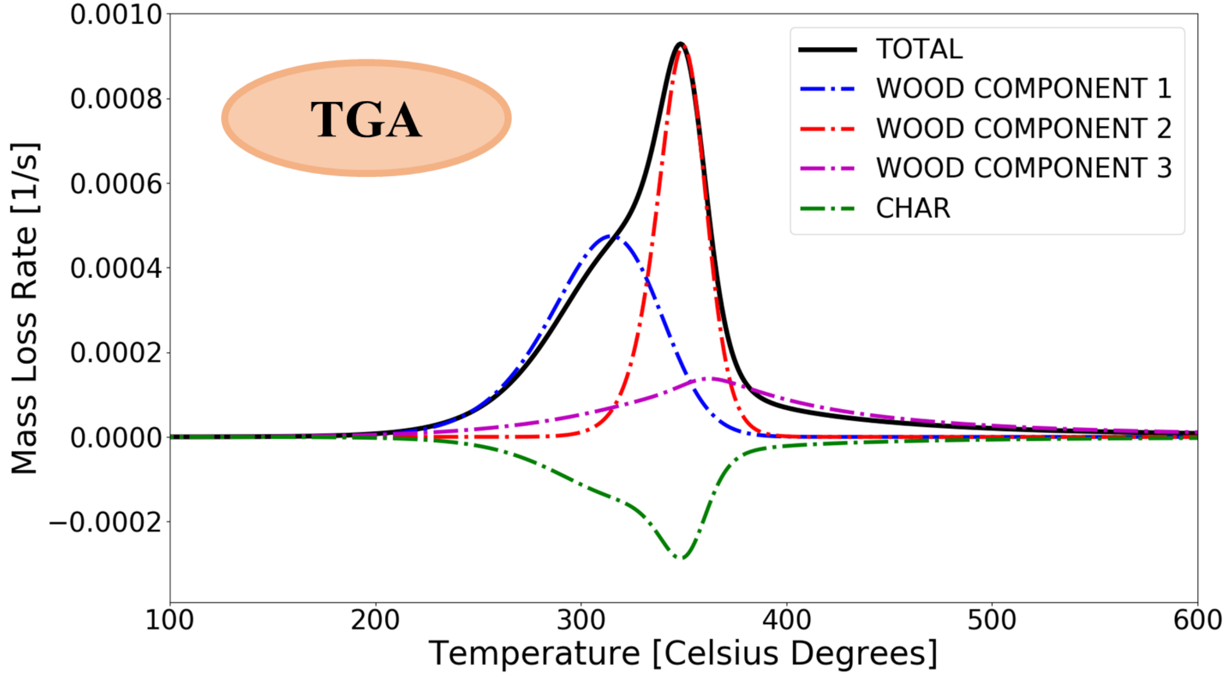
$$\boxed{\dot{q}'' = \dot{m}\Delta H_C}$$



ANAMET. Fire Testing Technology Ltd. http://www.anamet.cz/vyrobce/fire-testing-technology-ltd (cited 26.11.2019).

Complex Pyrolysis Modeling

- Heat transfer, heat conduction, decomposition kinetics, combustion, smoke production and transport, etc.
  -> complicated – a lot of input parameters
- Both gas and solid phase solved at the same time



$$\nu_1\ \textit{Wood component 1} \longrightarrow \nu_{CH,1}\ \textit{Char} + \textit{Combustible gases}$$
$$\nu_2\ \textit{Wood component 2} \longrightarrow \nu_{CH,2}\ \textit{Char} + \textit{Combustible gases}$$
$$\nu_3\ \textit{Wood component 3} \longrightarrow \nu_{CH,3}\ \textit{Char} + \textit{Combustible gases}$$

Consequence vs. Complex Modeling

Consequence modeling parameters
Pyr. gas composition
Soot yield
Density
Heat conductivity
Specific heat
Emissivity
Heat release rate
Ignition temperature

11 vs. 30

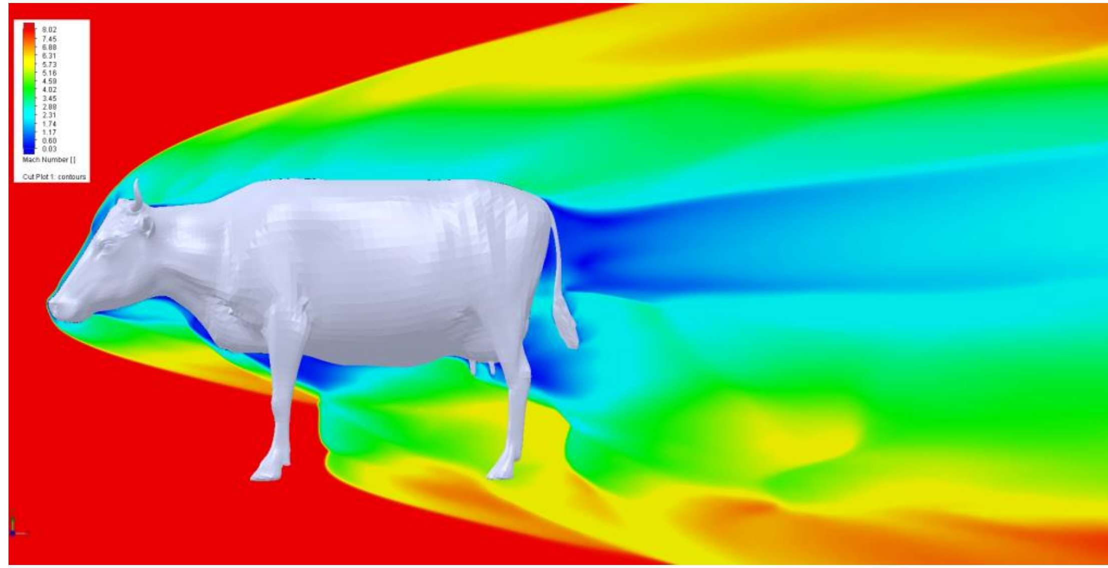
Complex modeling parameters	*How to obtain*
Pyr. gas composition	El. analysis, lit.
Soot yield	Cone calorimetry
Density	Directly, lit.
Heat conductivity	Exp., literature
Specific heat	DSC, literature
Emissivity	Literature
Char density	Directly, lit.
Char heat cond.	Exp., literature
Char specific heat	DSC, literature
Char emissivity	Literature
Preexp. factor	TGA – opt.
Activation energy	TGA – opt.
Order of reaction	TGA – opt.
Heat of reaction	DSC
Heat of combustion	Cone calorimetry
Stoch. coeff. of char	TGA
Stoch. coeff. of decomposing comp.	TGA – opt.

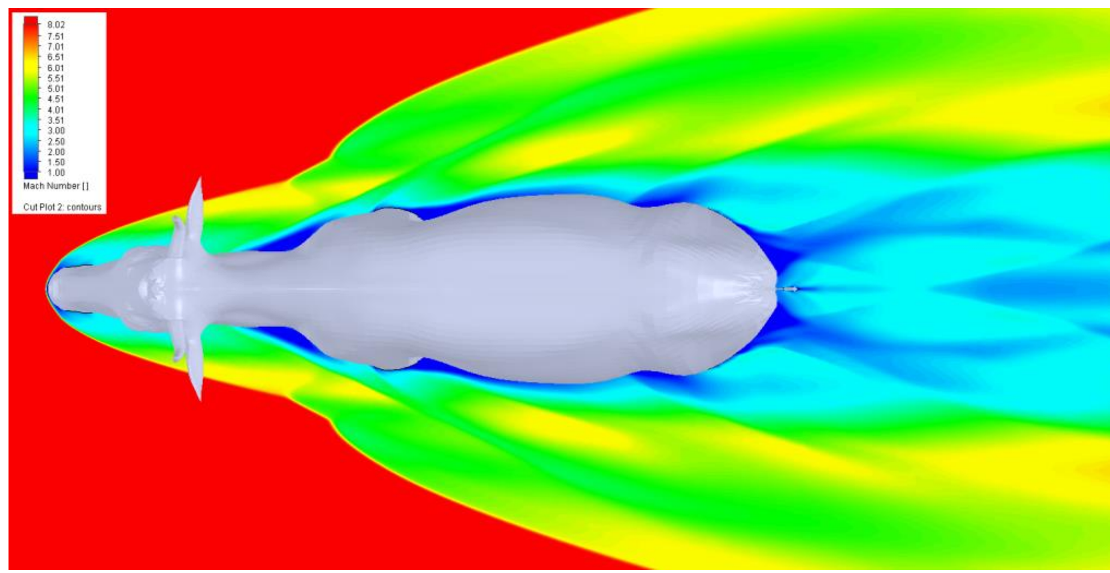
- Is 11 enough? For which scenario?
- Validation!

Validation

- Mach 8 cow
  (1000+ mph)
- Does it make sense?

- Compare to experiment
- Costly experiments





Mentor. Can Cows Fly? FloEFD Investigates. Part 3 – Superbly Sonic. https://blogs.mentor.com/robinbornoff/blog/2015/10/12/can-cows-fly-floefd-investigates-part-3-superbly-sonic/ (cited 26.11.2019)

RCT (Room Corner Test)

- Test facility to determine Reaction to fire of facing materials (walls and ceilings)
- Burner location and fire load according to ISO 9705-1
- Room 2,4 x 3,6 x 2,4 m + hood 3 x 3 m + exhaust duct
- Walls covered by OSB board

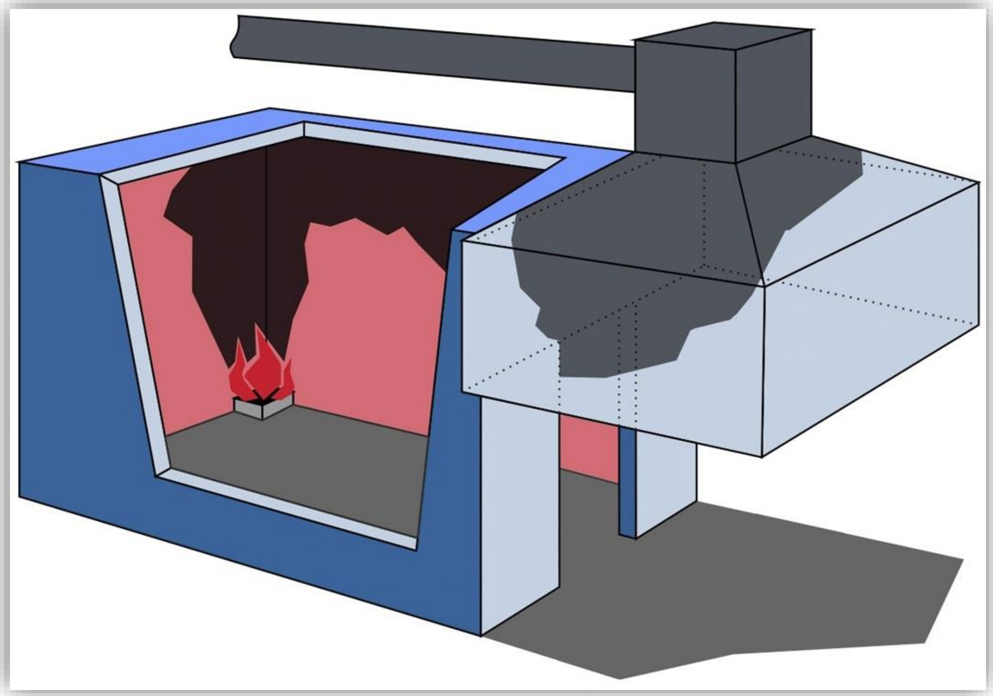
INTERNATIONAL STANDARD

ISO 9705-1

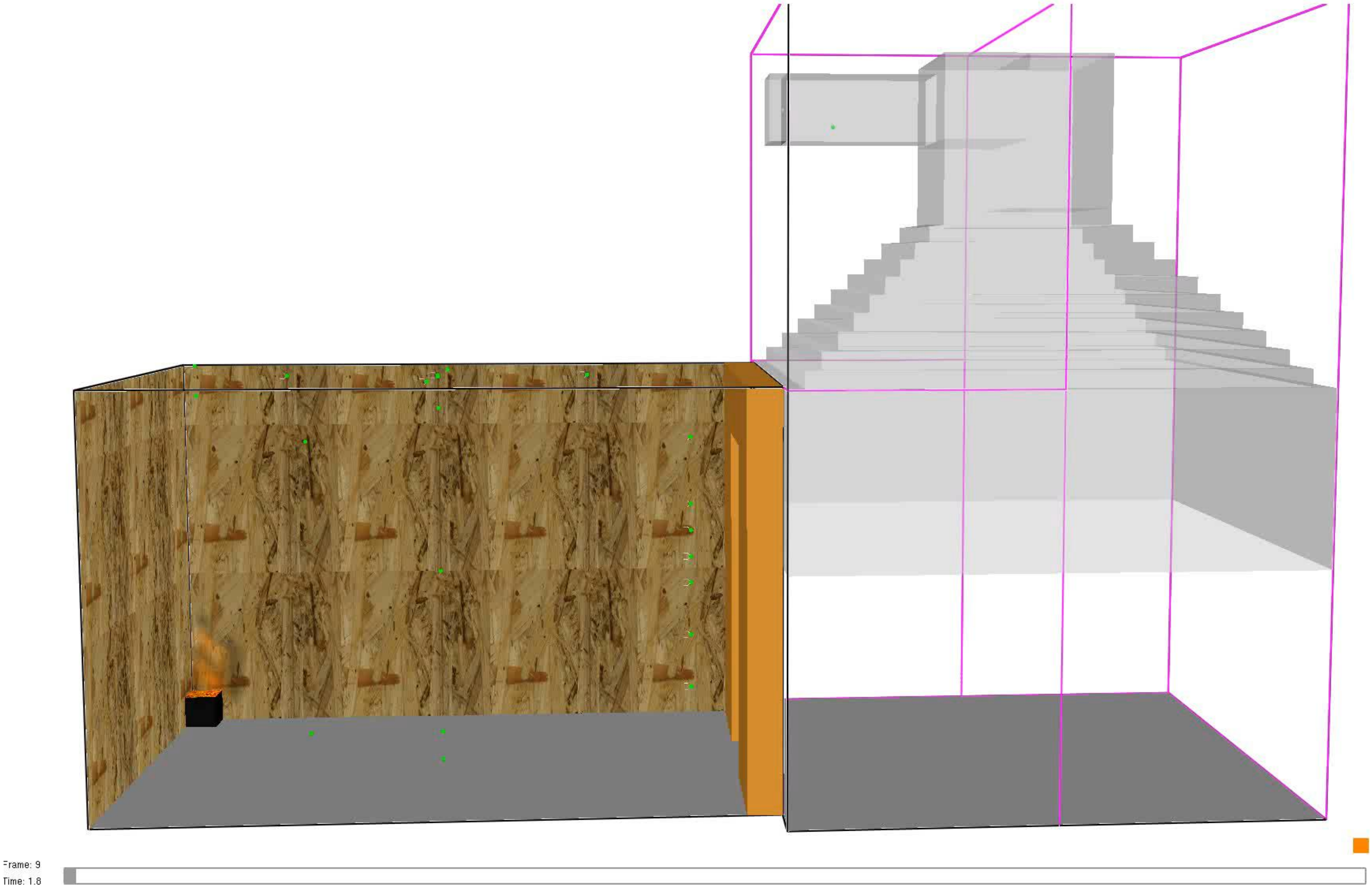
First edition
2016-02-15

Reaction to fire tests — Room corner test for wall and ceiling lining products —

Part 1:
Test method for a small room configuration



Room Corner Test – FDS model

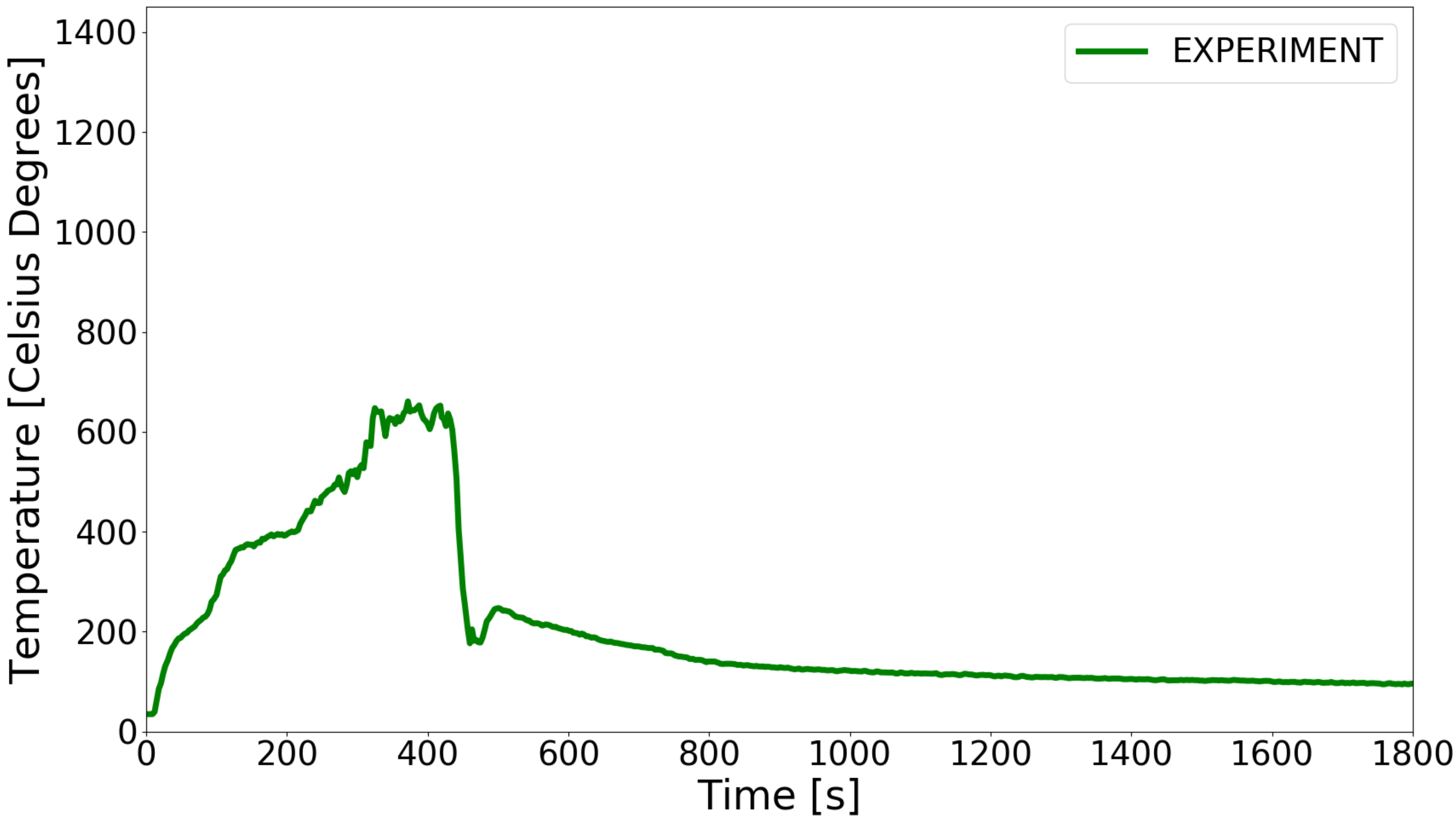


Investigated Material - OSB

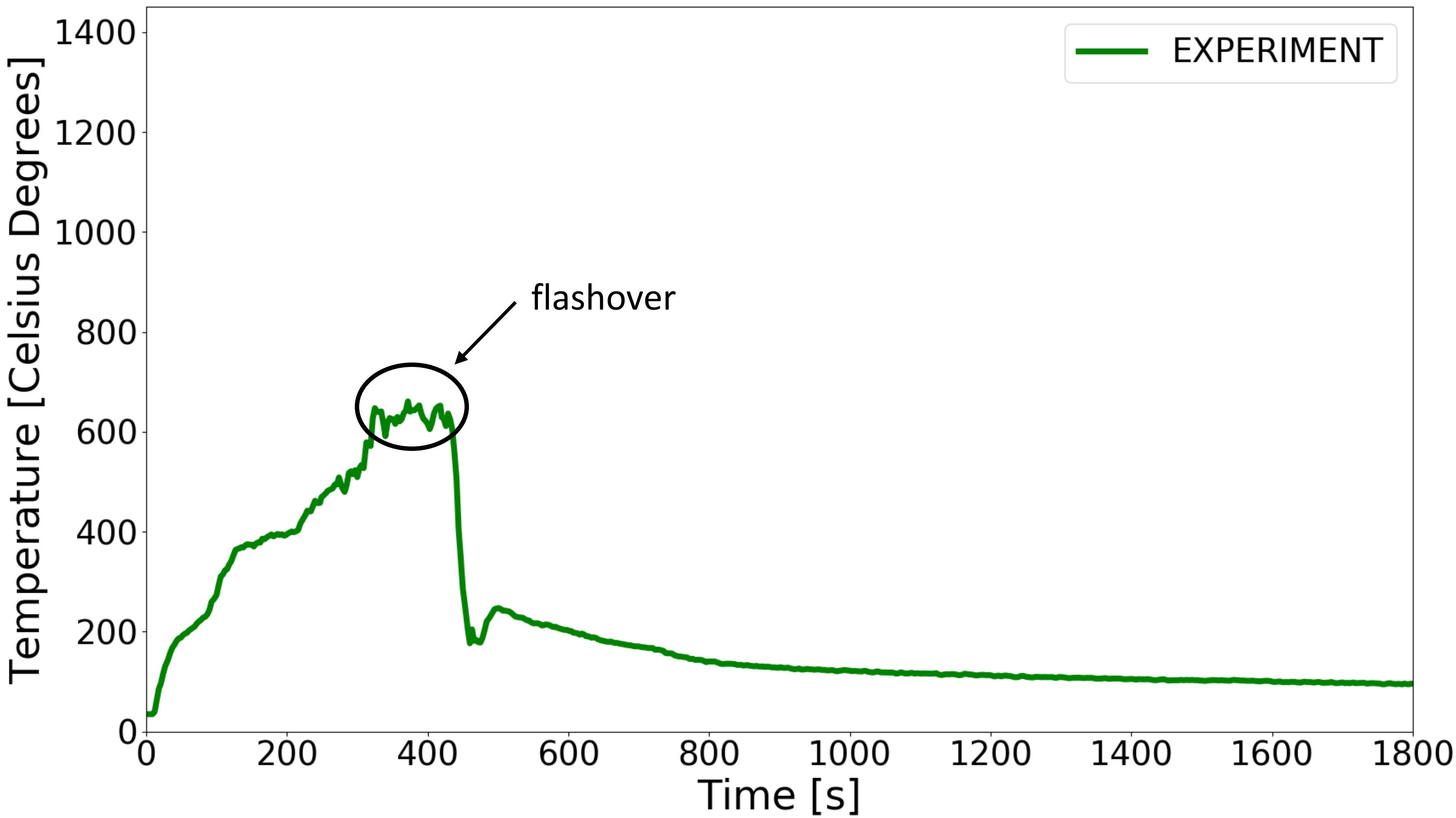
- Engineered/Composite board
- Building material, insulation, interiors
- Charring, inhomogeneous
- Complex chemical structure
  (lignin, cellulose, hemicellulose)
  + adhesives + additives

- Future
  - spruce wood

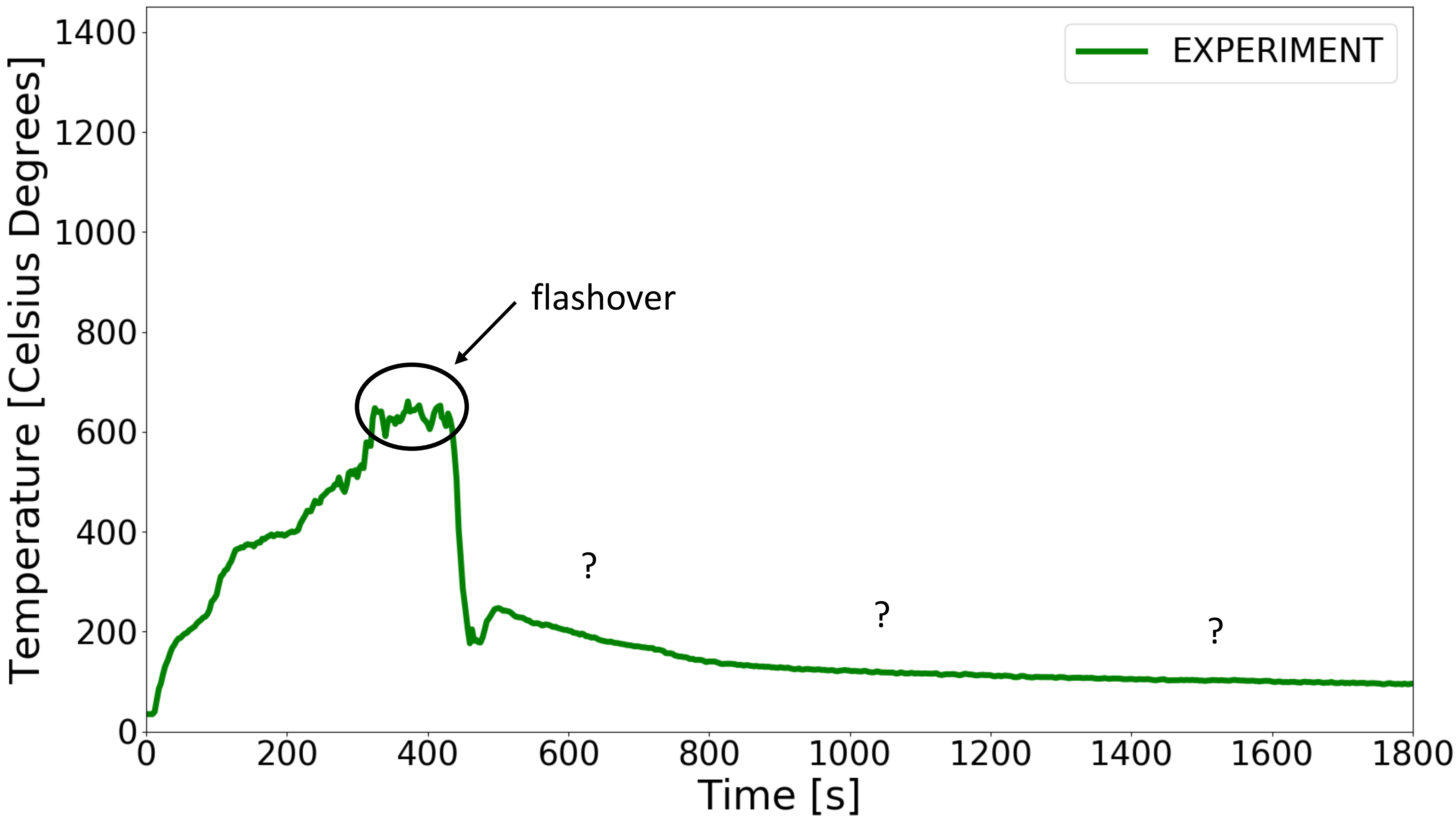
Experimental Data - Thermocouple



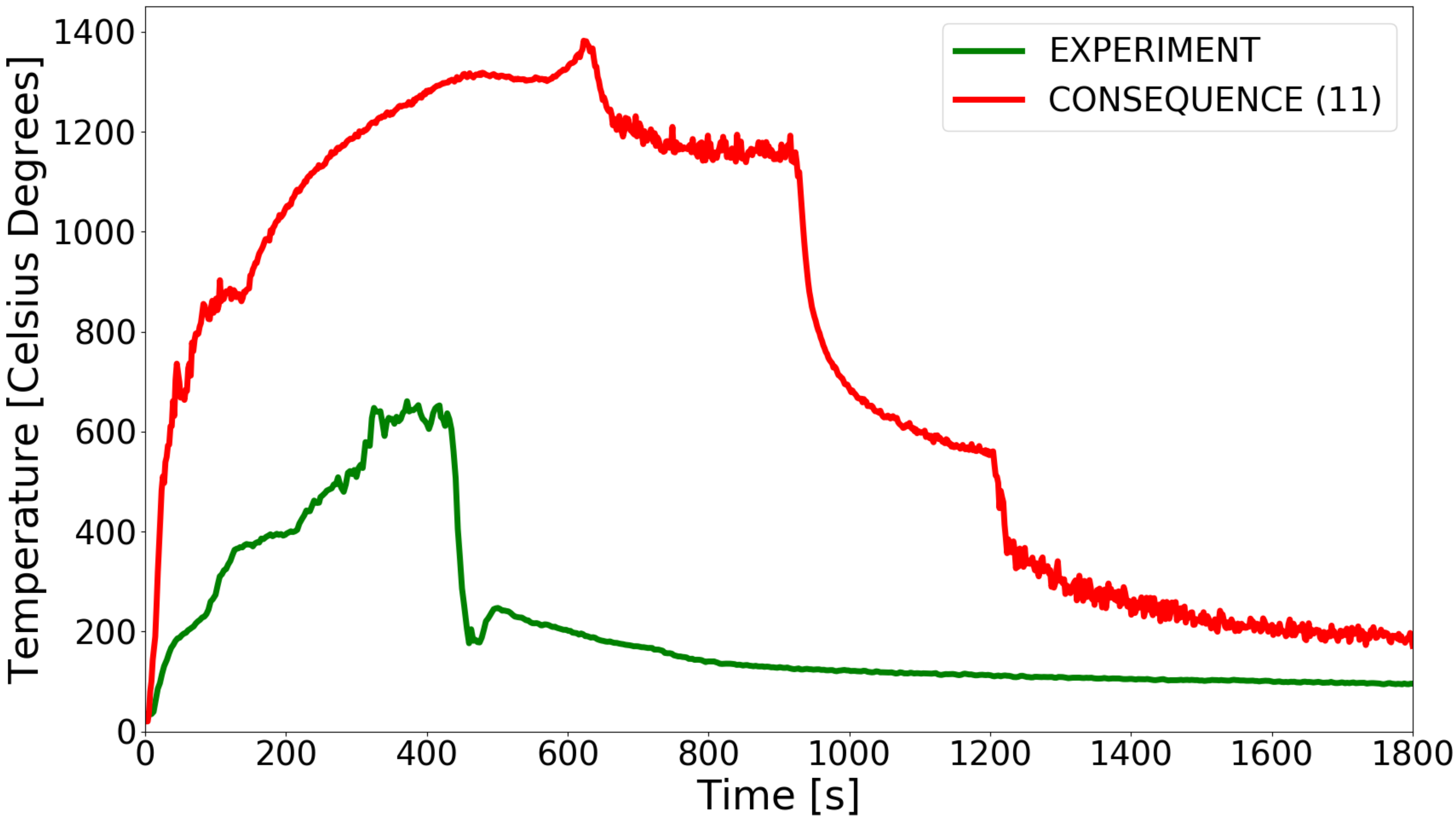
Experimental Data - Thermocouple



Experimental Data - Thermocouple



Experimental Data - Comparison



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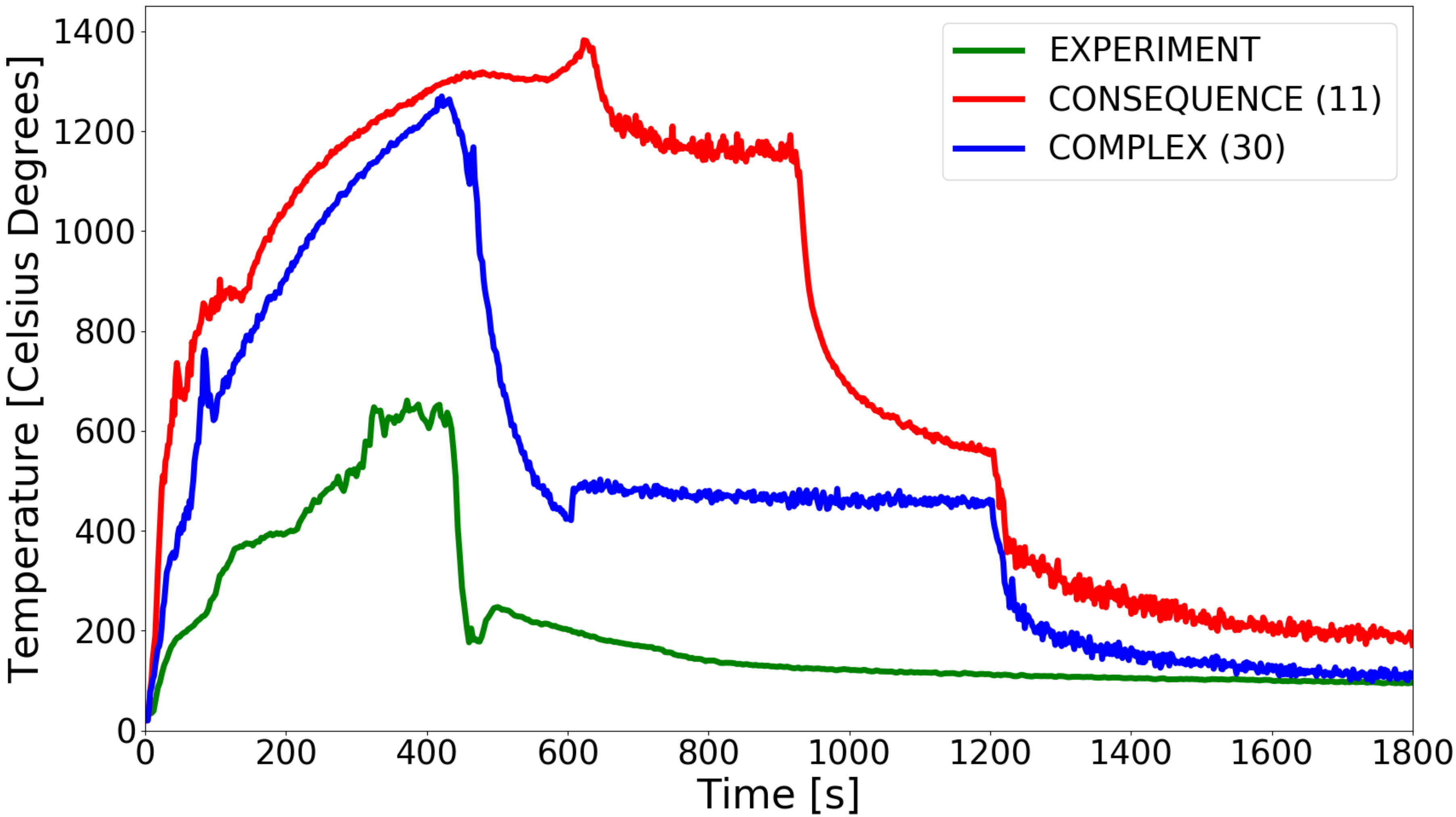
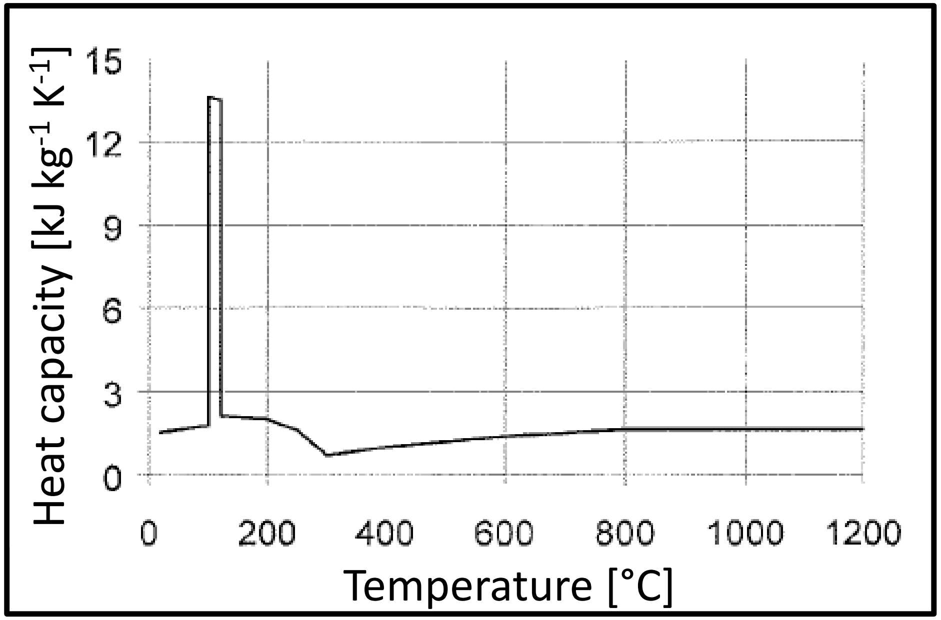
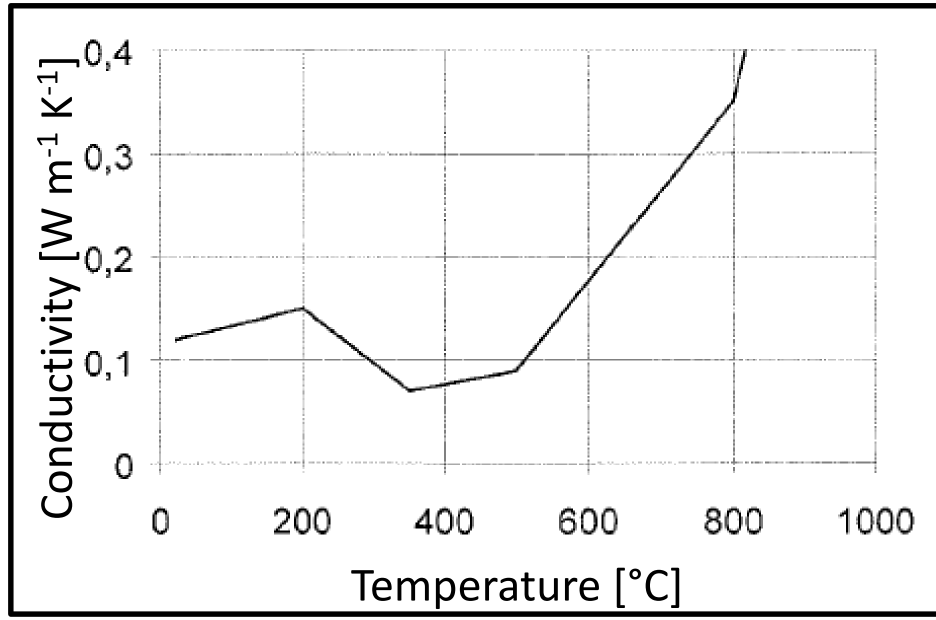


Temperature Dependent Properties

- Eurocode ČSN EN 1995-1-2





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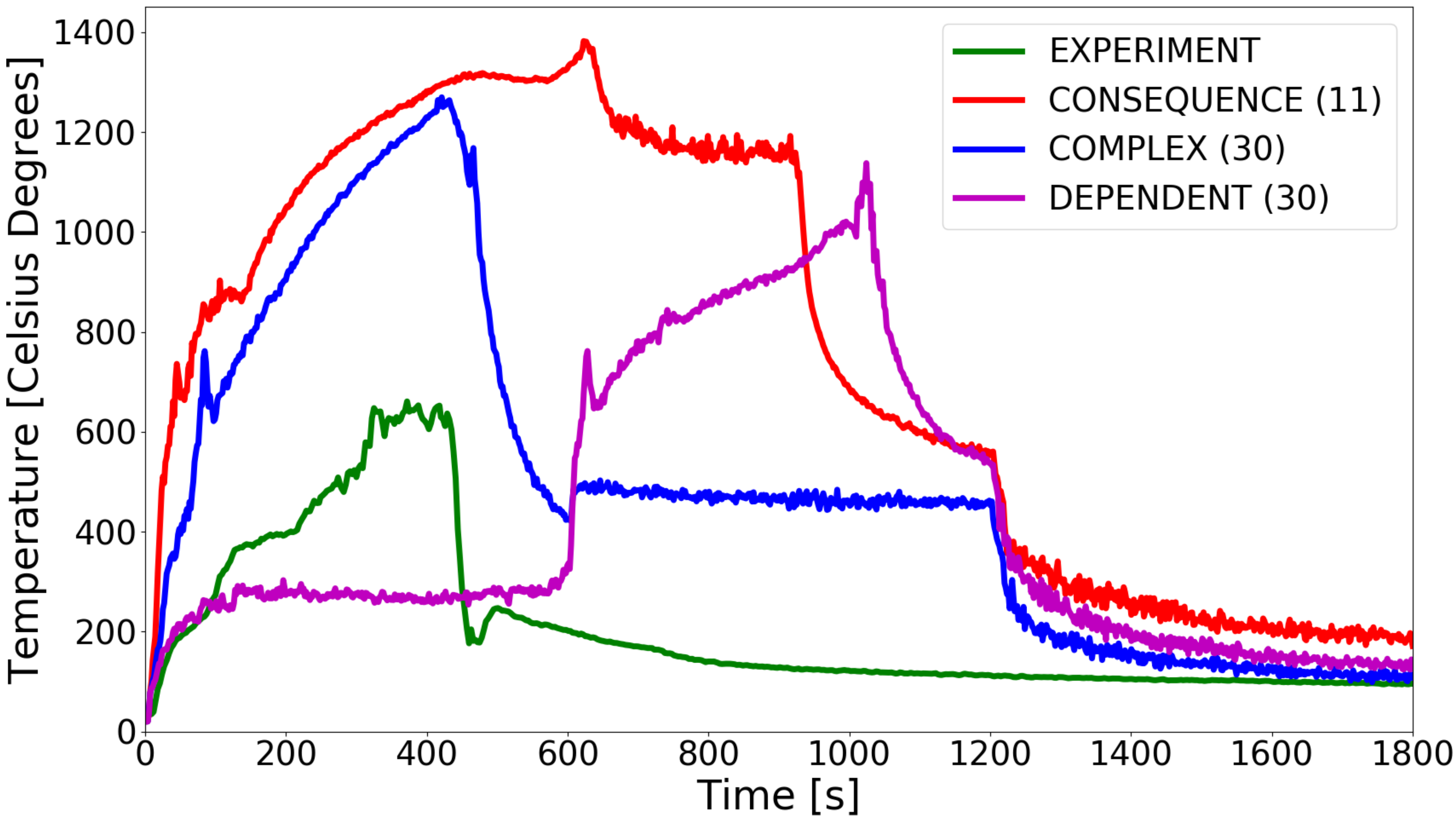
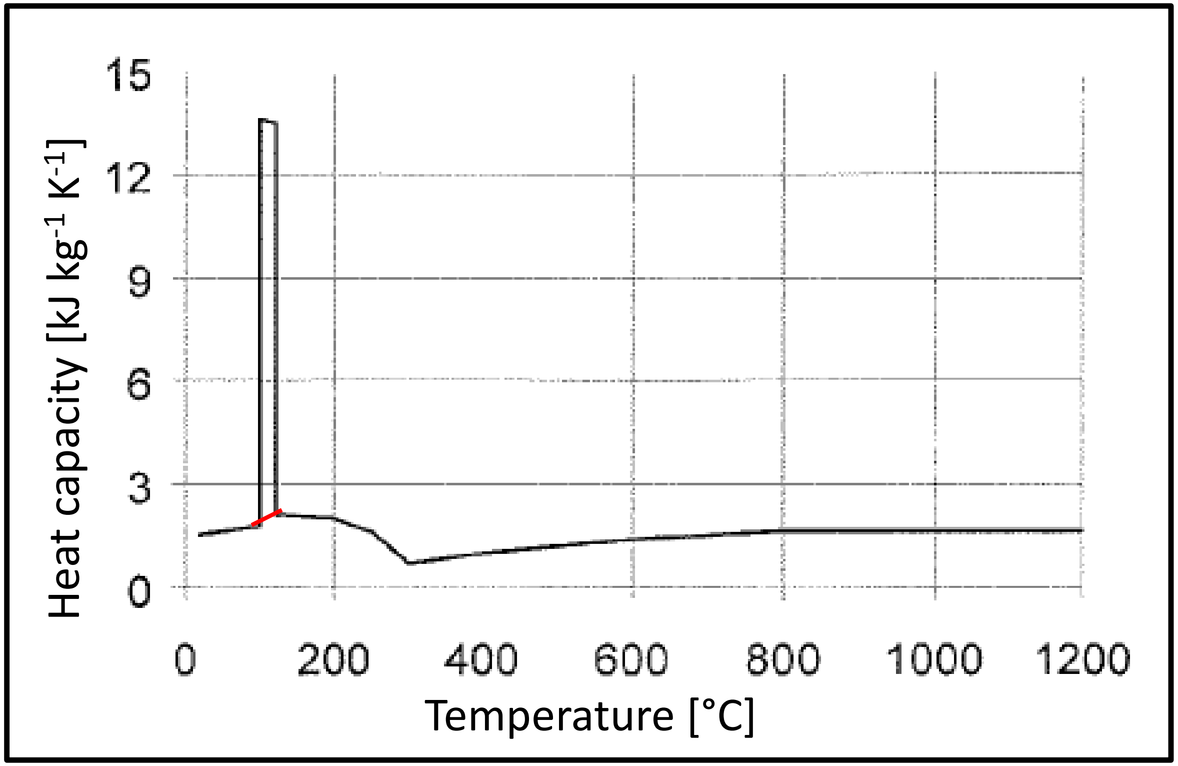
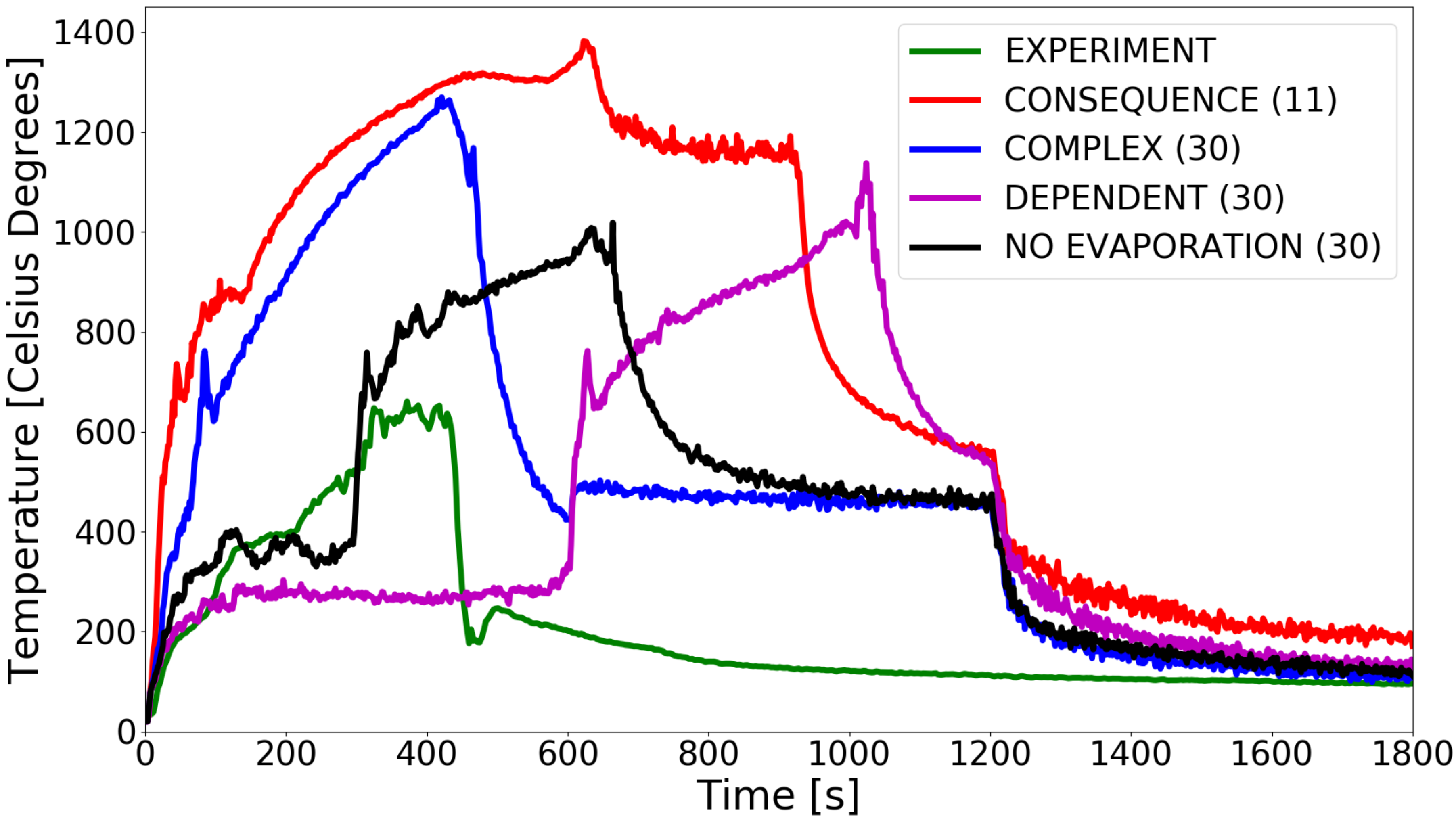


Temperature Dependent Properties

- Eurocode ČSN EN 1995-1-2
- No evaporation



Experimental Data - Comparison



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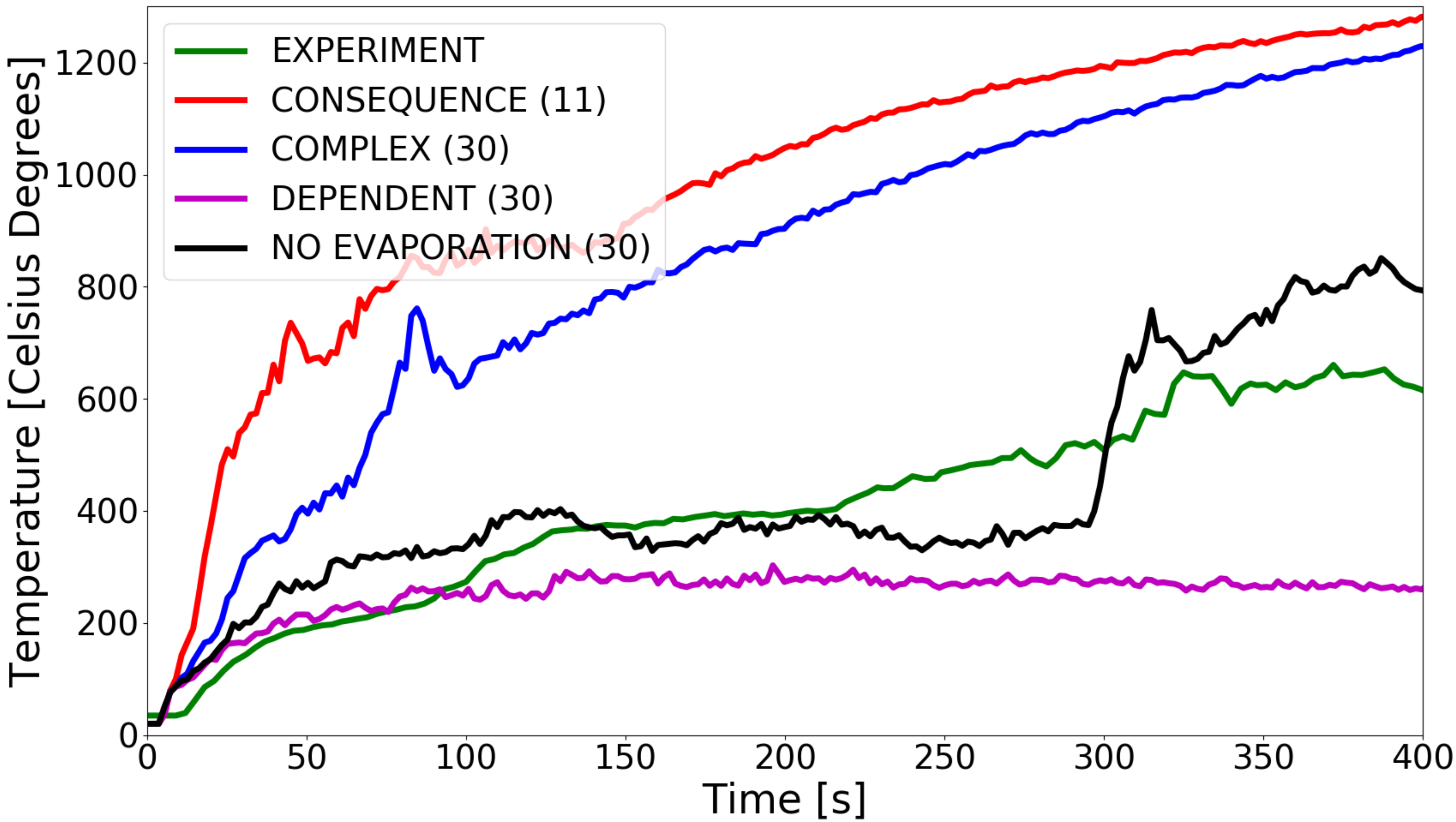


Conclusions and Future Work

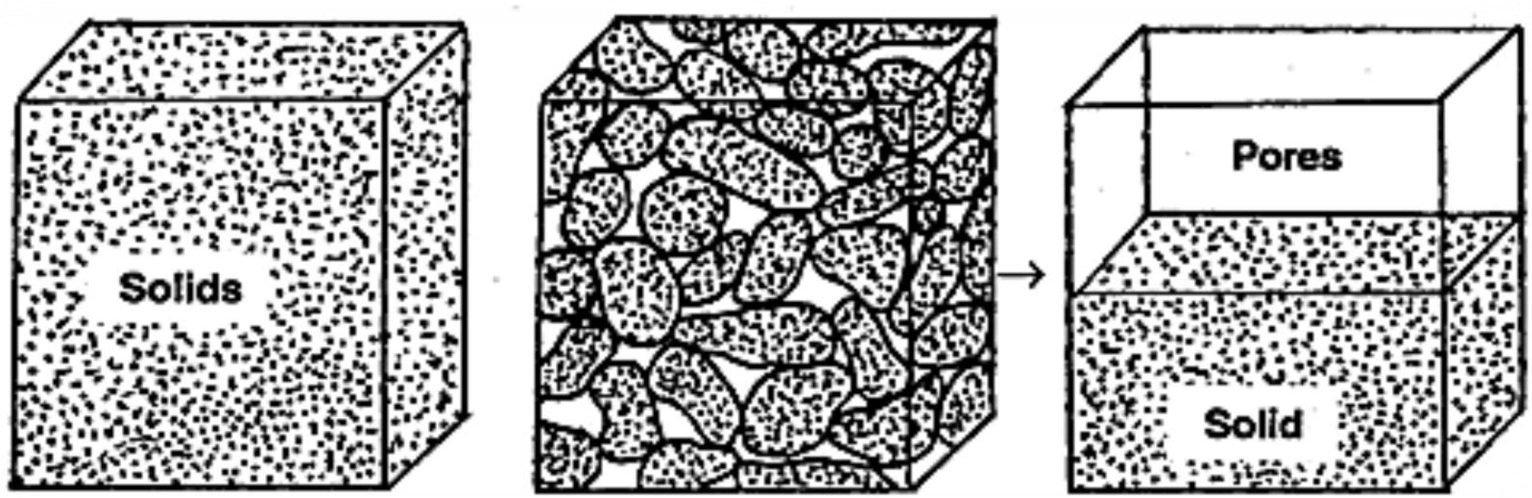
- Different pyrolysis models in RCT for OSB board
- HRR modeling insufficient
- Thermal properties most significant

- Thermal properties from cone (PROPTI)
- Coupling with structural solvers
- More detailed char analysis

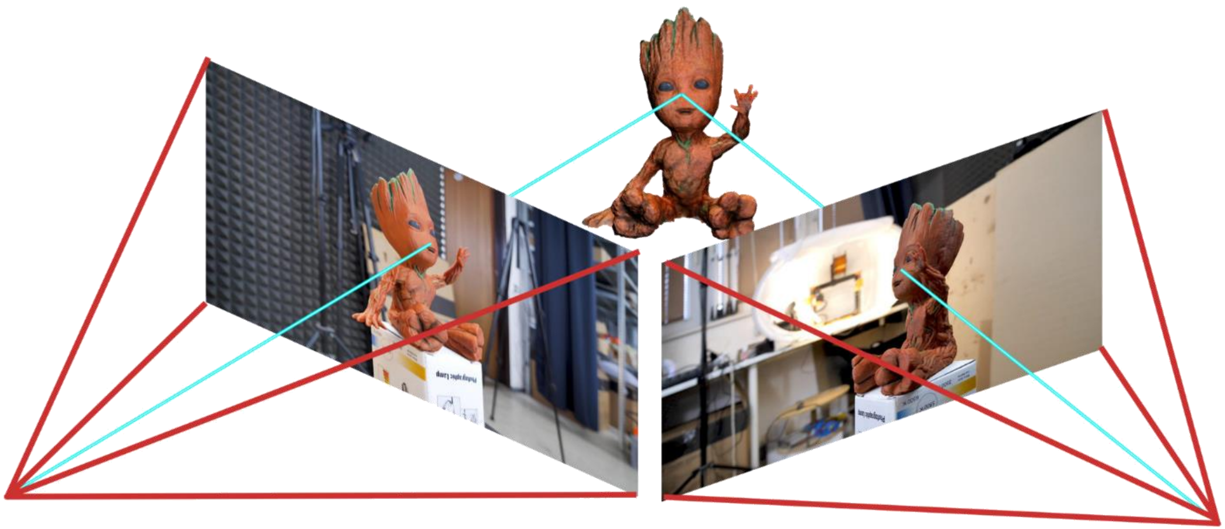
Measuring Char Bulk Density

- Bulk density
- Archimedes
- Gas or liquid pycnometry rejected

$$\rho = \frac{m}{V}$$

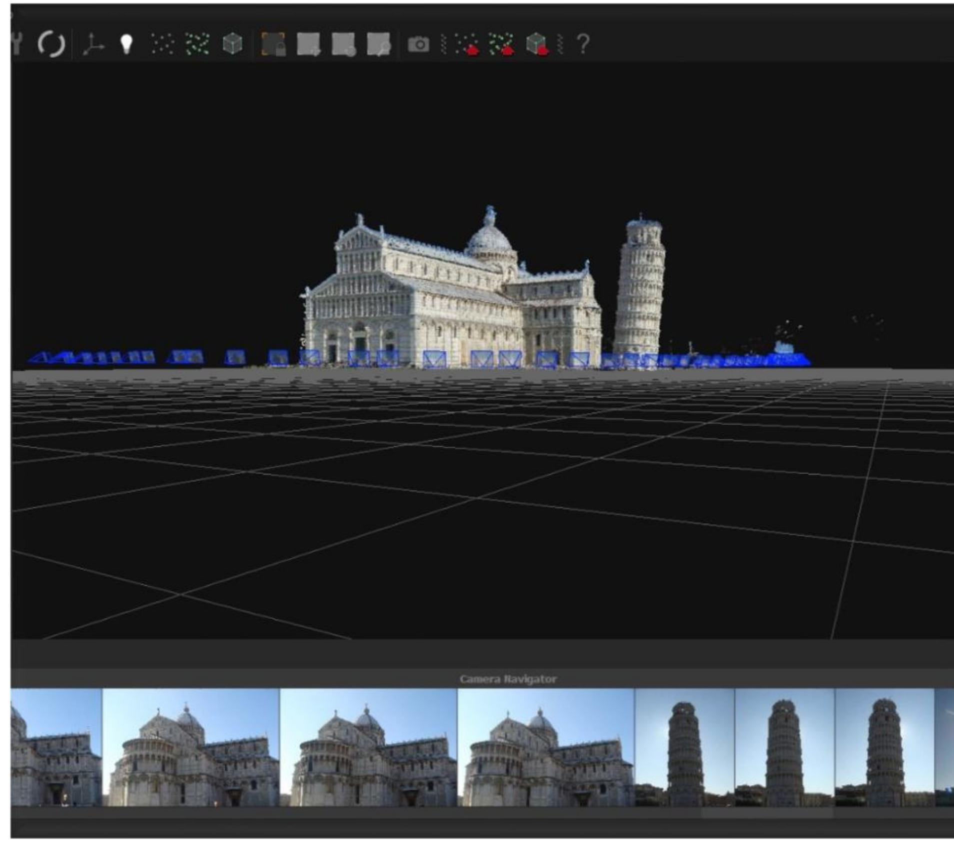


Photogrammetry

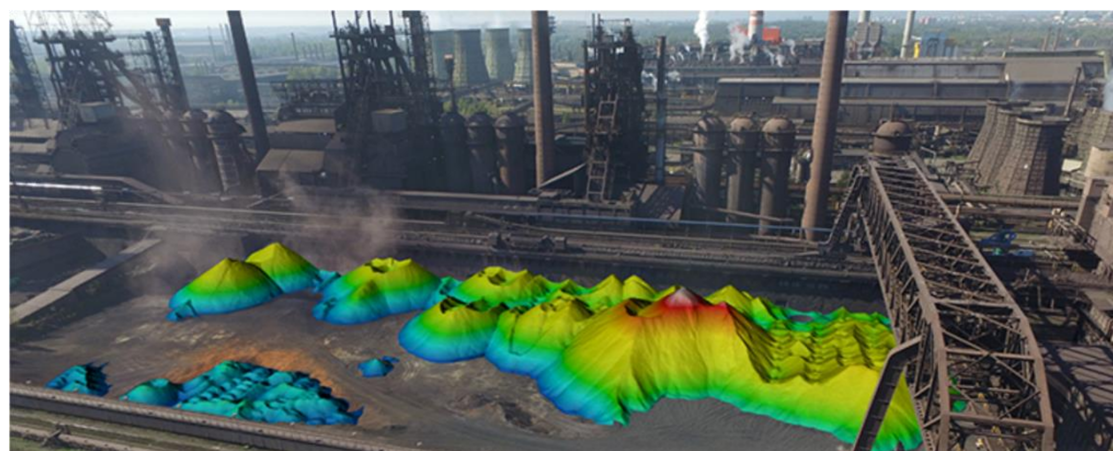


Photogrammetry

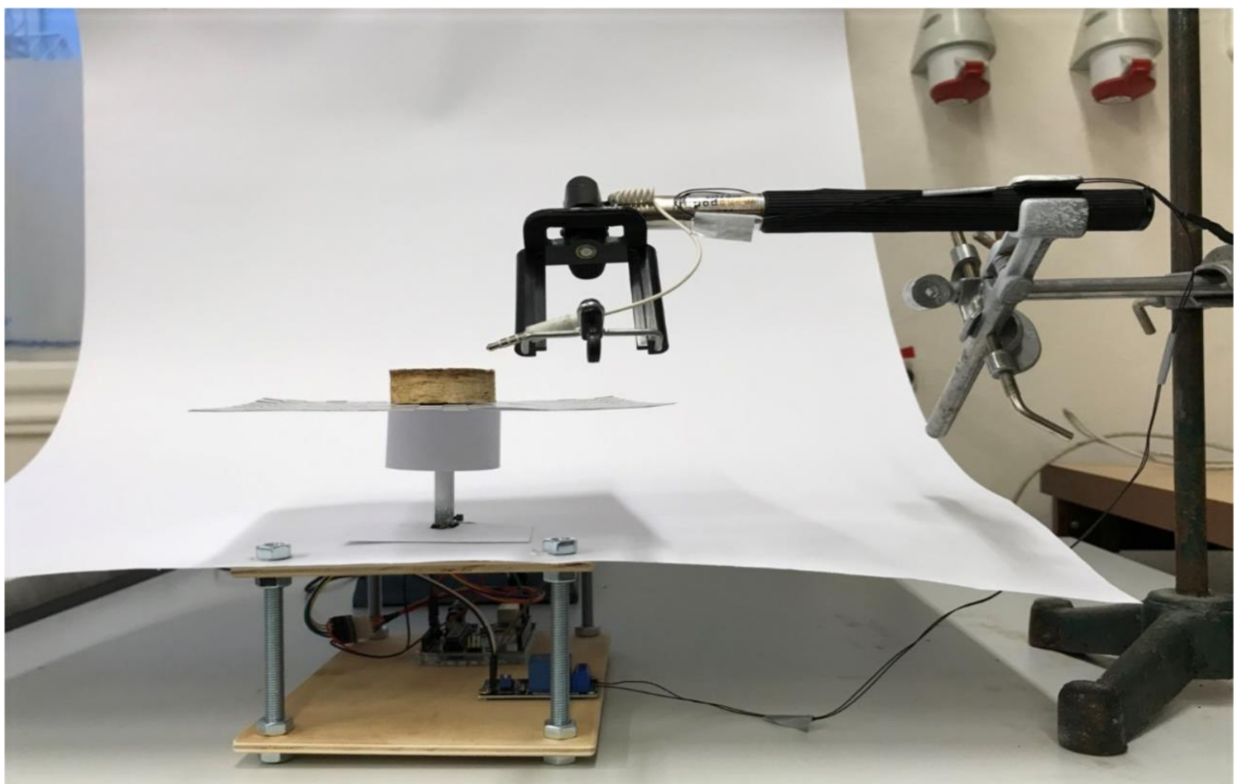
- Software
  - Colmap
  - Meshroom
  - VisualSMF
  - Reality Capture
  - Zephyr3D



NVIDIA CUDA



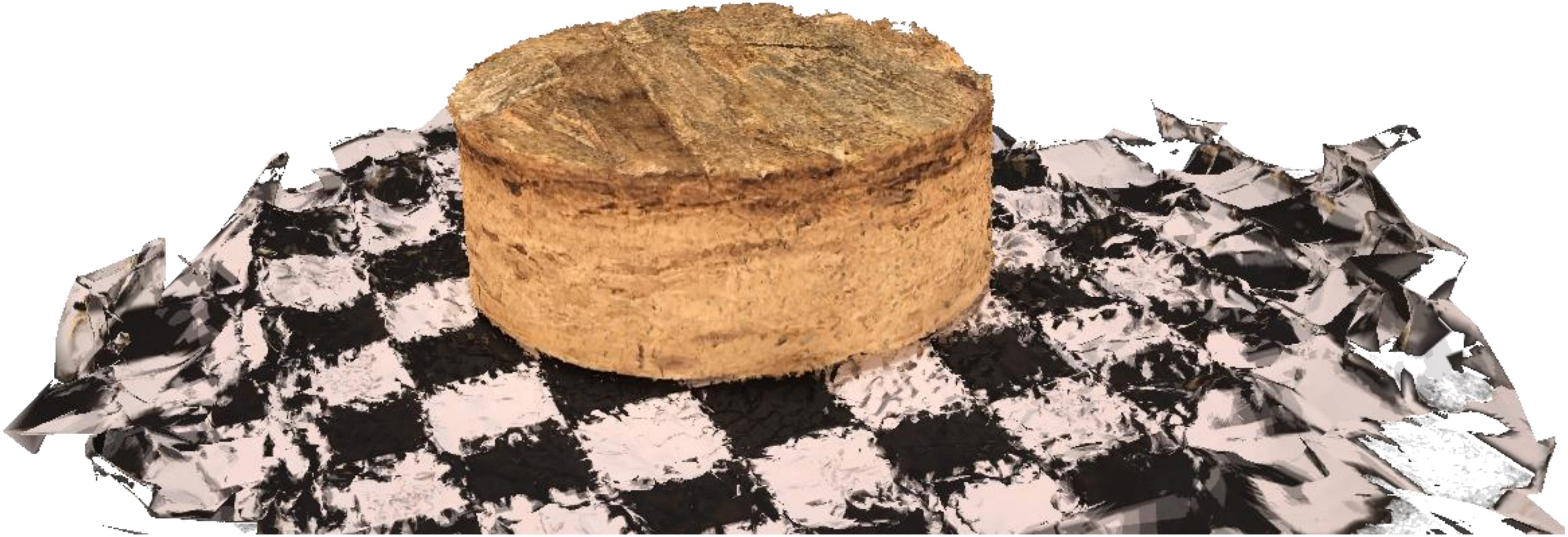
Photogrammetry



Photogrammetry

Photogrammetry

- Price approximately 60 Euro
- Improvements in future
- Methodology



Thank you for your attention

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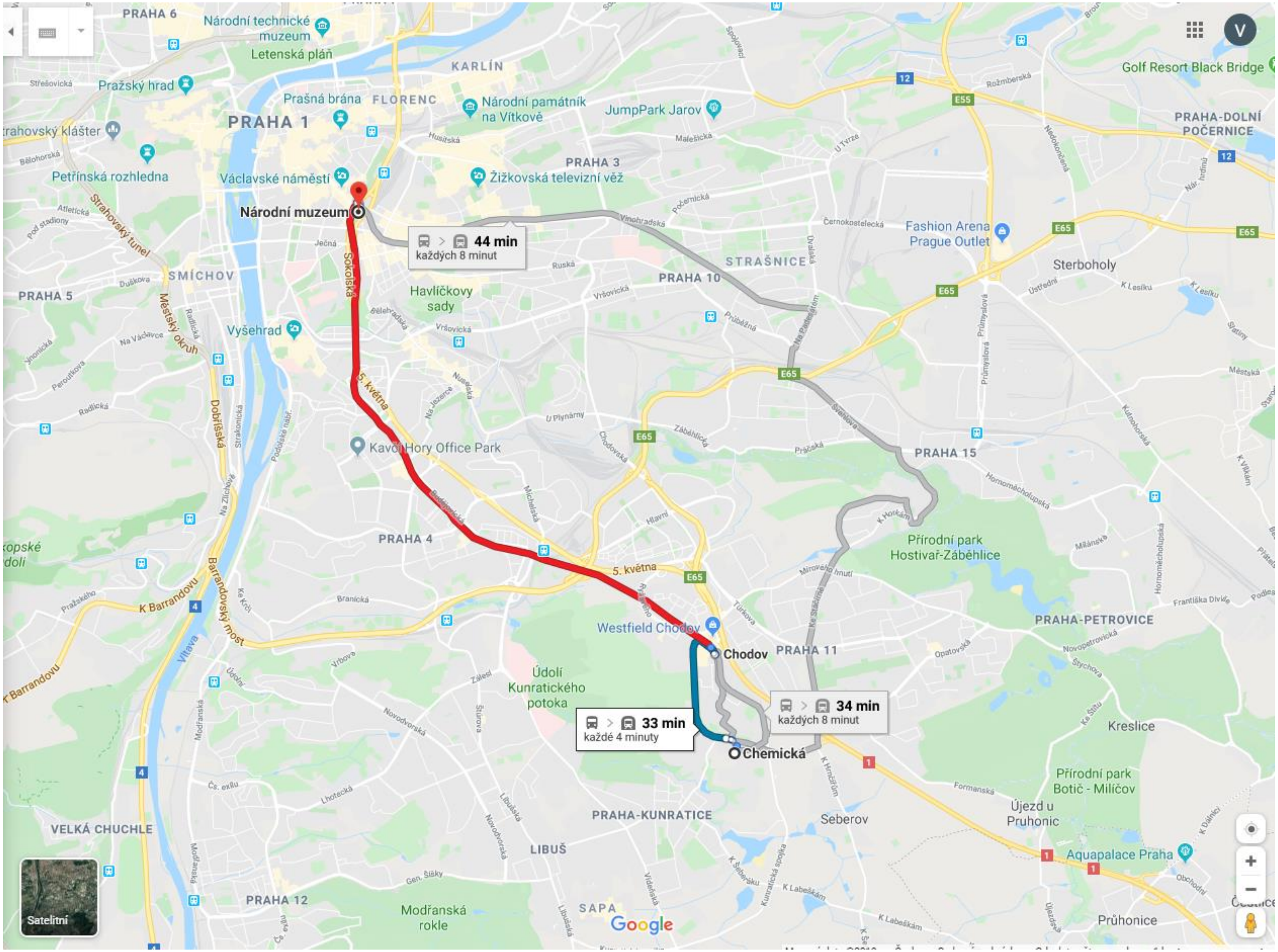
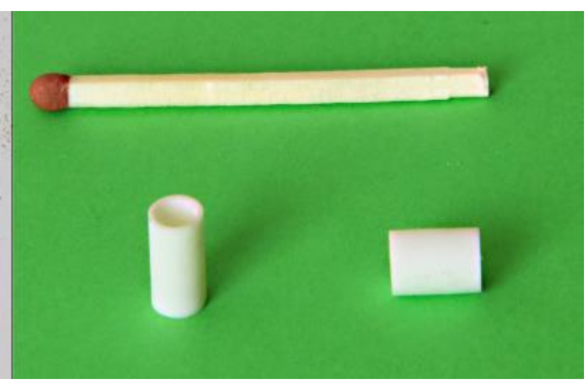
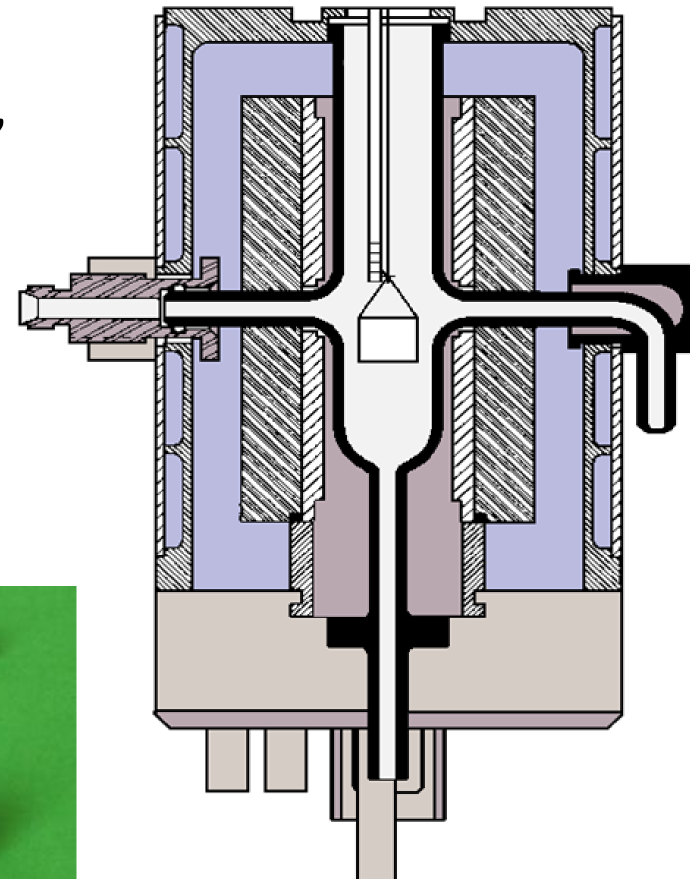


TGA – Thermogravimetric Analysis

- Samples heated on precise scales, constant heating rate
- Processes connected to mass loss, **thermal decomp. reaction scheme**, **kinetic parameters** (indirectly, optimization)
- In nitrogen, heating rate 5 °C/min, 6-9 mg homogeneous samples





Source: TA Instruments

$$\frac{\partial}{\partial t}(1 - Y_s) = r = k(T) f(1 - Y_s) \quad , \tag{2.1}$$

$$k_c = A \cdot e^{\left(\frac{-E_a}{RT}\right)} \quad , \tag{2.4}$$

$$r = \left(\frac{\rho}{\rho_0}\right)^N X_{O_2}^{N_{O_2}} A \ e^{\left(\frac{-E_a}{RT}\right)} \quad , \tag{2.5}$$

$$\rho c_p \frac{\partial T_s}{\partial t} = \frac{\partial}{\partial x}\left(k_s \frac{\partial T_s}{\partial x}\right) + \dot{q}_s''' \quad , \tag{2.7}$$

$$\dot{q}_{s,c}''' = -\rho_0 \sum_j r_j(x) \Delta H_j \quad , \tag{2.9}$$

$$-k_s \frac{\partial T_s}{\partial x}(0, t) = \dot{q}_c'' + \dot{q}_r'' \quad , \tag{2.10}$$

$$\dot{q}'' = \dot{m}'' \Delta H_c \quad . \tag{2.13}$$

$$r_k = \underbrace{(1 - \alpha_{A_k})^{n_k}}_{\text{reaction model}} \underbrace{A_k \exp\left(\frac{-E_k}{RT}\right)}_{\text{Arrhenius function}} \underbrace{X_{O_2}(x)^{n_{O_2,k}}}_{\text{oxidation function}} \underbrace{\max\left[0, S_{thr,A,k}(T_s - T_{thr,k})\right]^{n^{t,k}}}_{\text{power function}}$$