Wir schaffen Wissen – heute für morgen

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SFP Phase II simulation with PSI break away model

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- Reactions during zirconium fire propagation
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- Boundary Conditions
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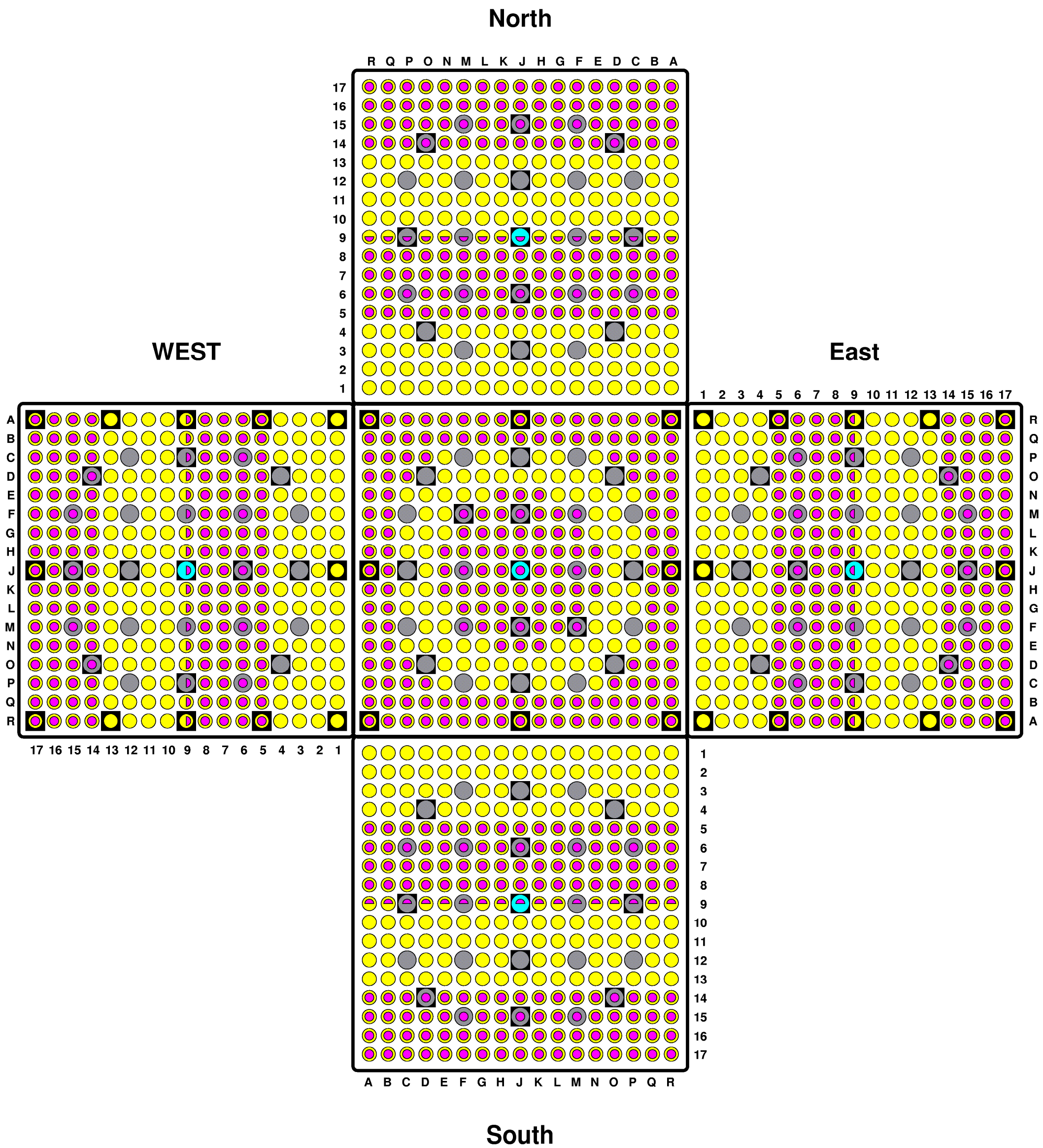
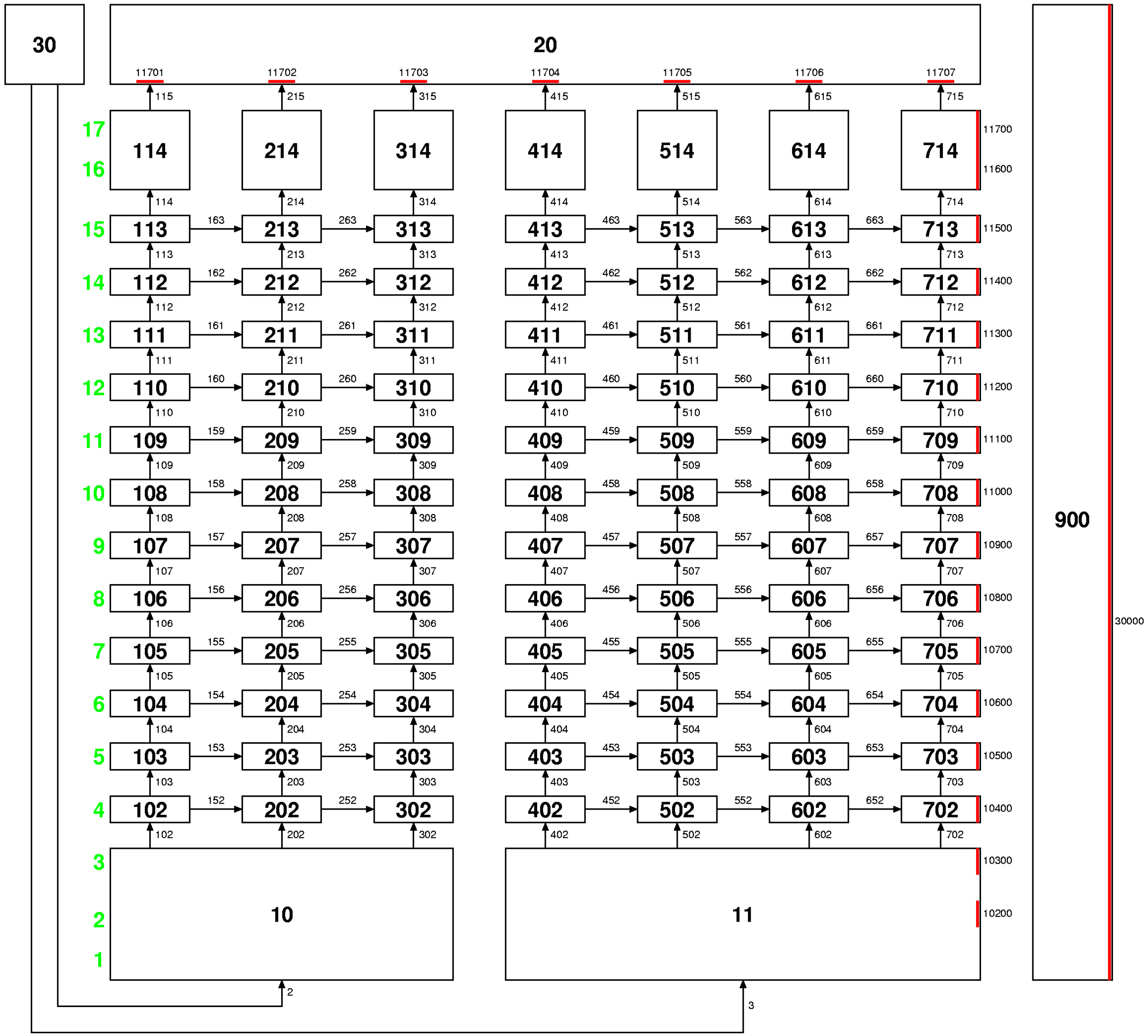
Nodalization I



7 Ring model with 3 rings in the central fuel element and 4 rings in the peripheral fuel elements

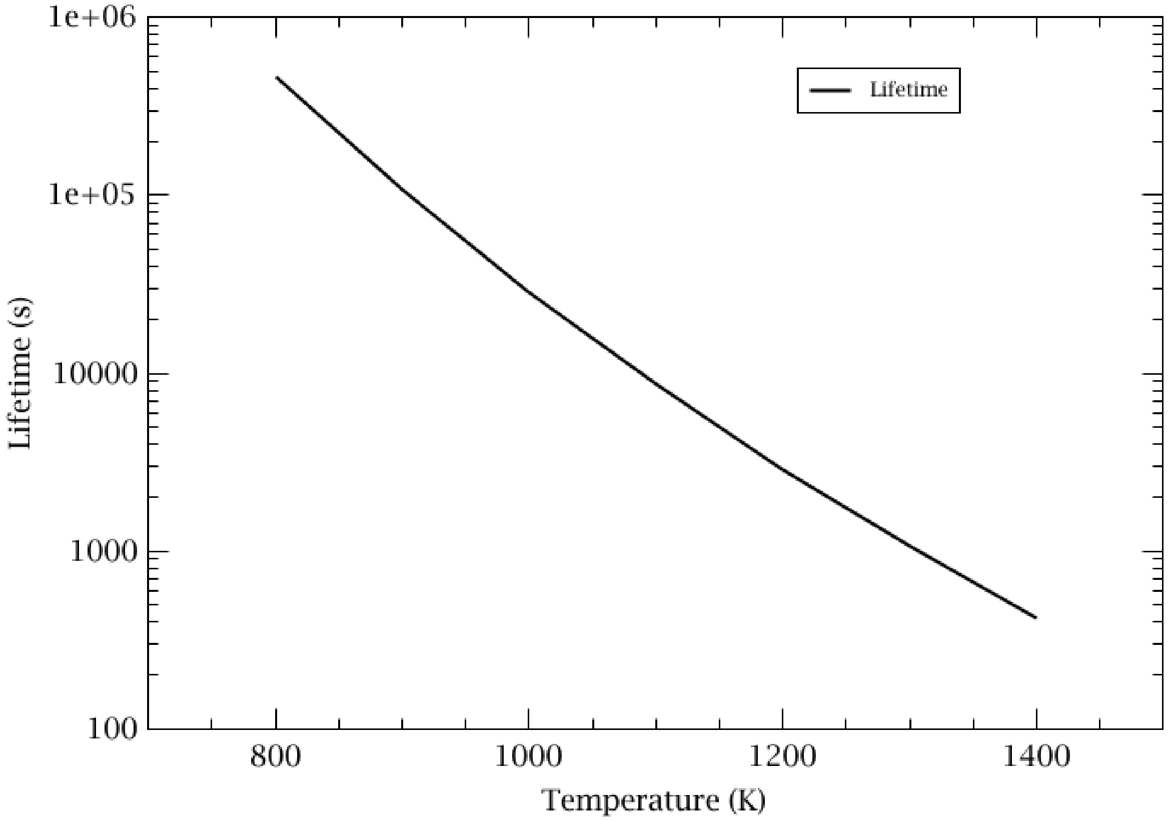
Nodalization II



Chemical Reactions

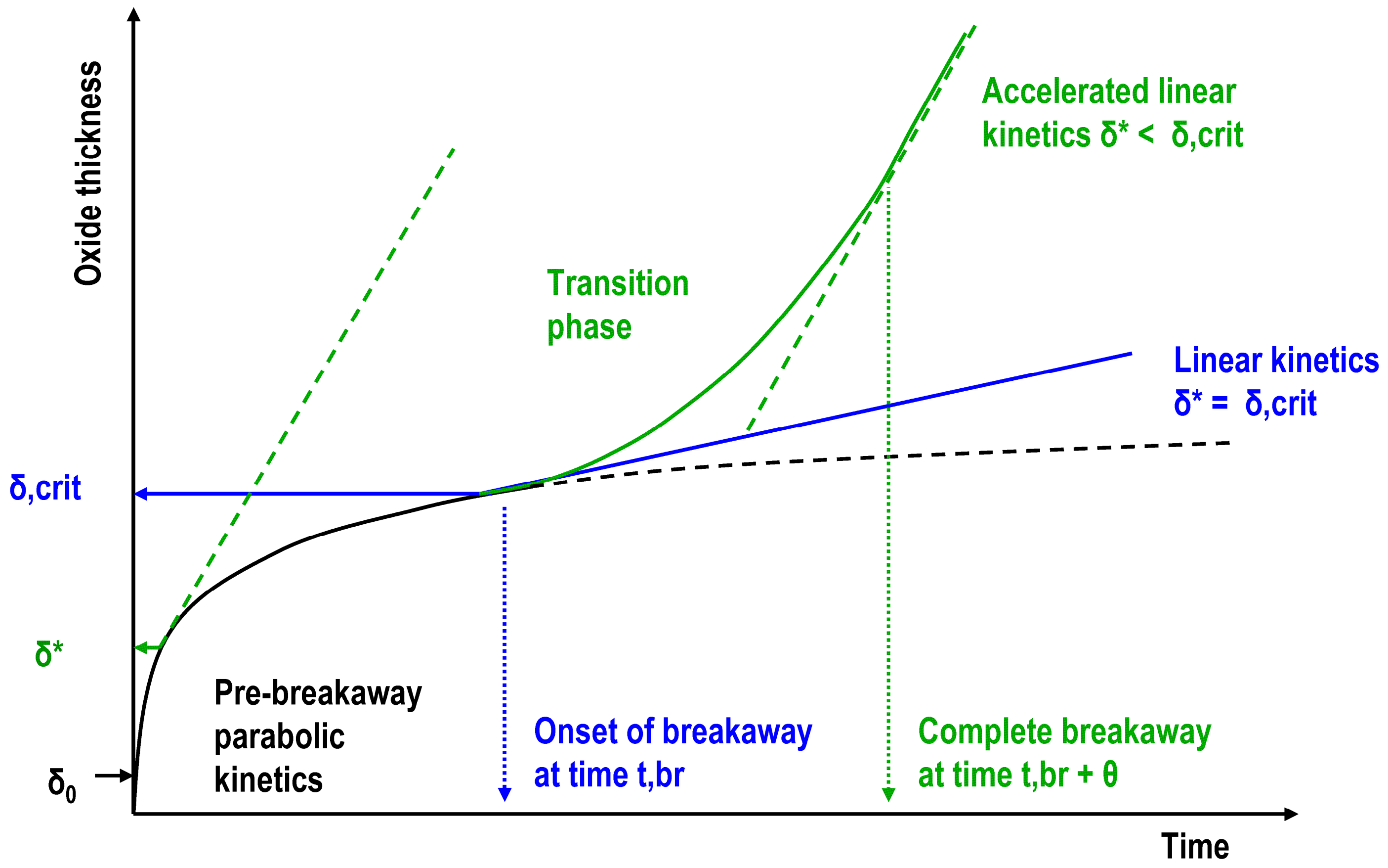
$Zr + O_2$	$\xrightarrow{1080\ kJ/mol}$	ZrO_2	modelled
$Zr + ½N_2$	$\xrightarrow{365\ kJ/mol}$	ZrN	not modelled
$ZrN + O_2$	$\xrightarrow{715\ kJ/mol}$	$ZrO_2 + ½N_2$	not modelled
$Zr + CO_2$			not modelled
$Zr + H_2O$			neglected

MELCOR Break Away Model



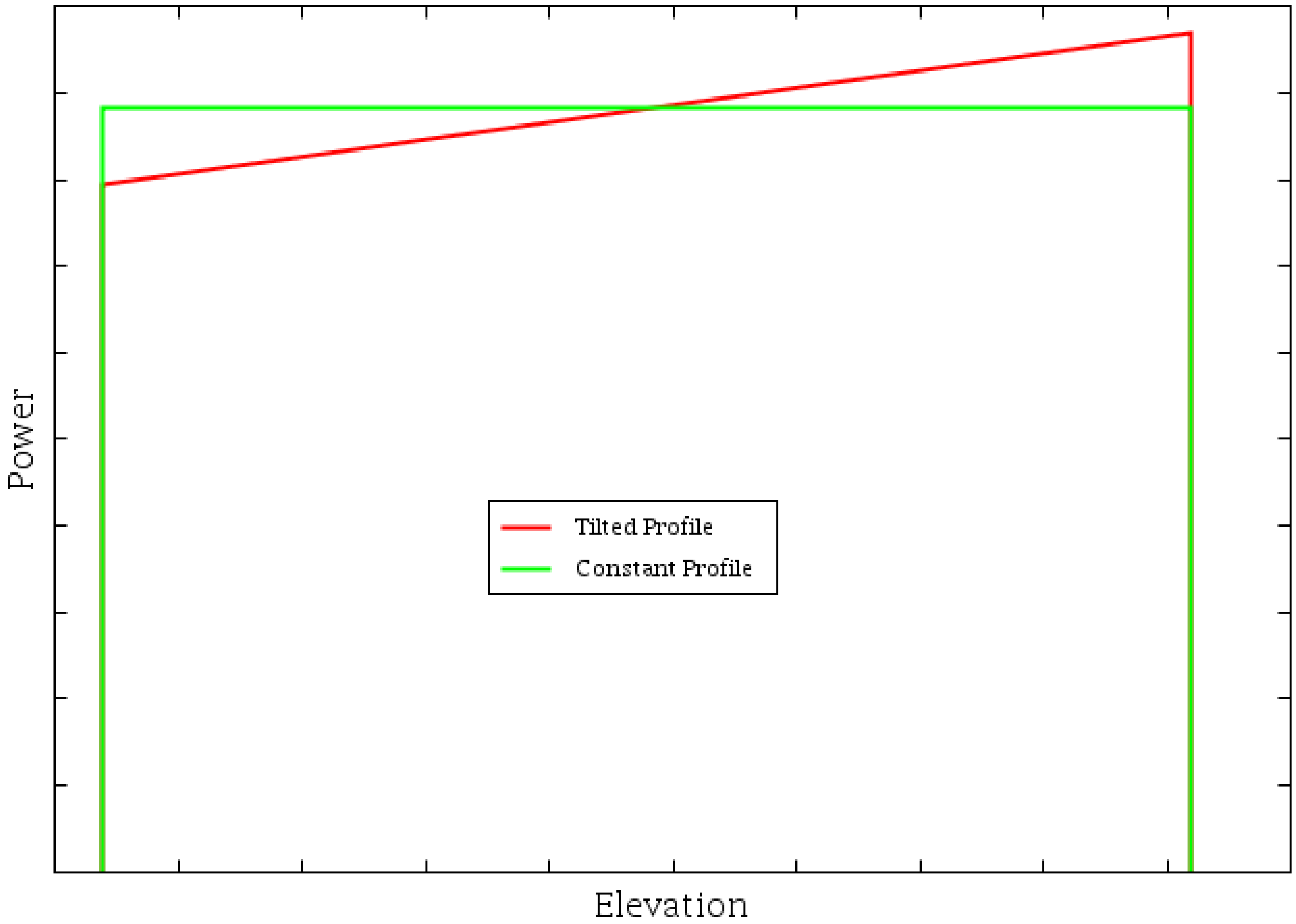
MELCOR breakaway model is based on lifetime only if O_2 is available. If the integrated lifetime is reached the air oxidation rate function changes from pre breakaway to post breakaway during a transition time.

PSI Break Away Model



PSI breakaway model is based on temperature dependent oxide layer thickness if N_2 is available. If the δ,crit is reached the effective thickness changes from δ,crit to δ* during a transition time.

Boundary Conditions



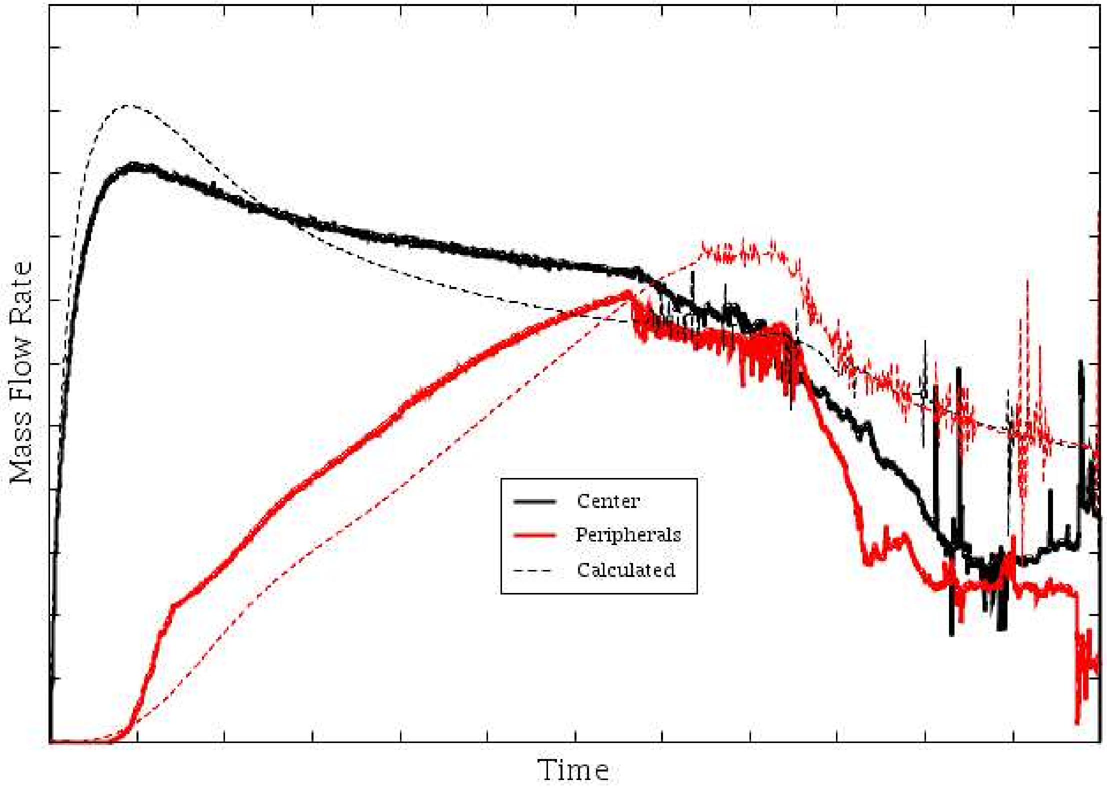
Temperature dependency in heater wire resistance implies higher power at higher temperatures along the length of the heater rod.

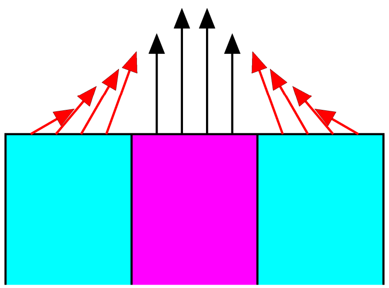
Boundary Conditions for presented calculation

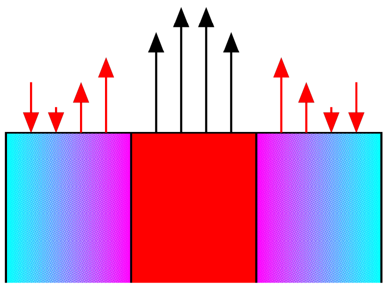
For the following calculation the boundary conditions are selected as follows:

Reaction rate function: Hofmann-Birchley (4 temp. regions)
Tilted power profile
PSI breakaway model activated
Buoyancy driven air flow
Switch off heating power at failure temperature of heater wires
Atmospheric pressure of Albuquerque
Air temperature at room temperature

Boundary Conditions



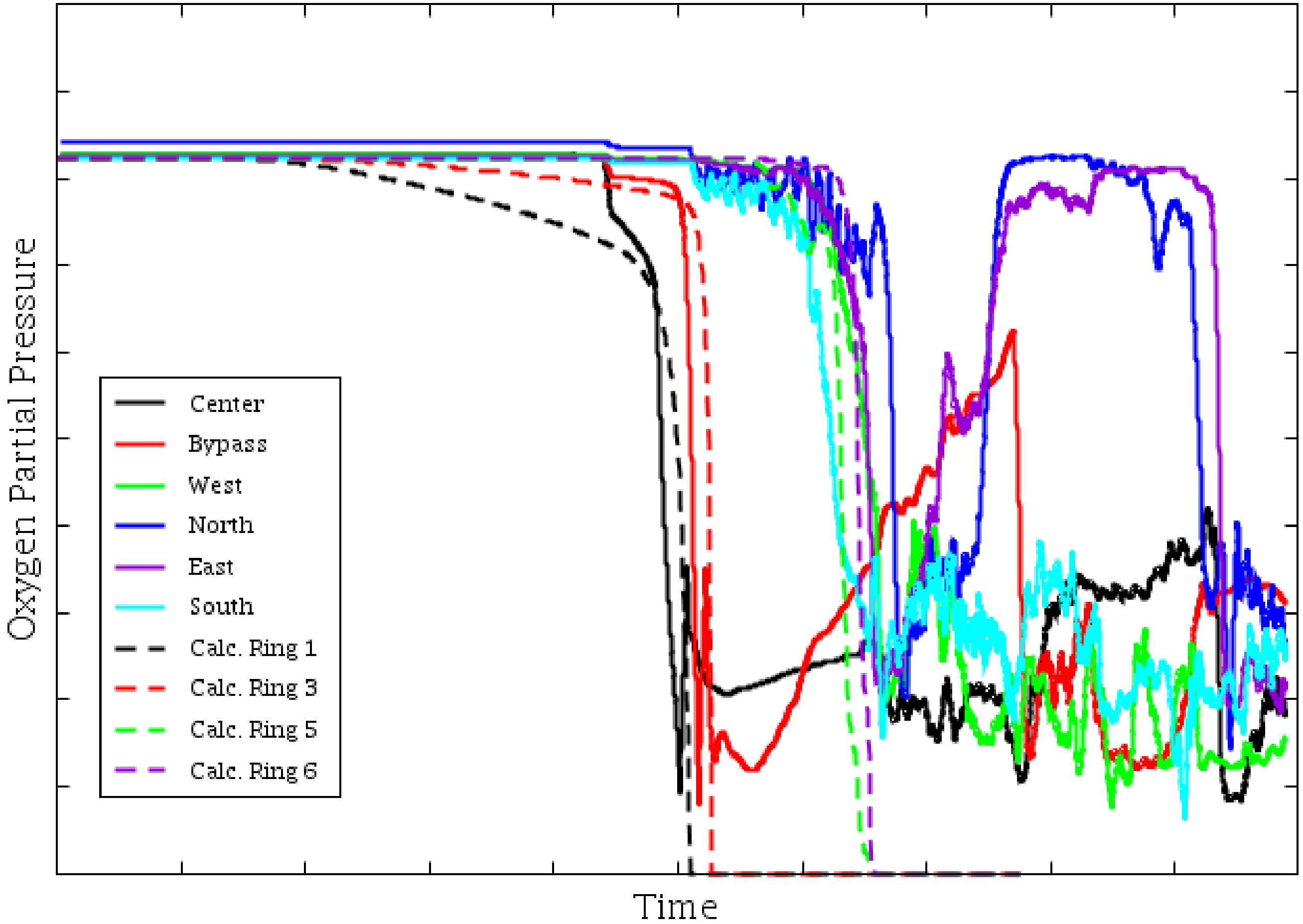




1 m^3 Air in Albuquerque (Mile High City) contains:

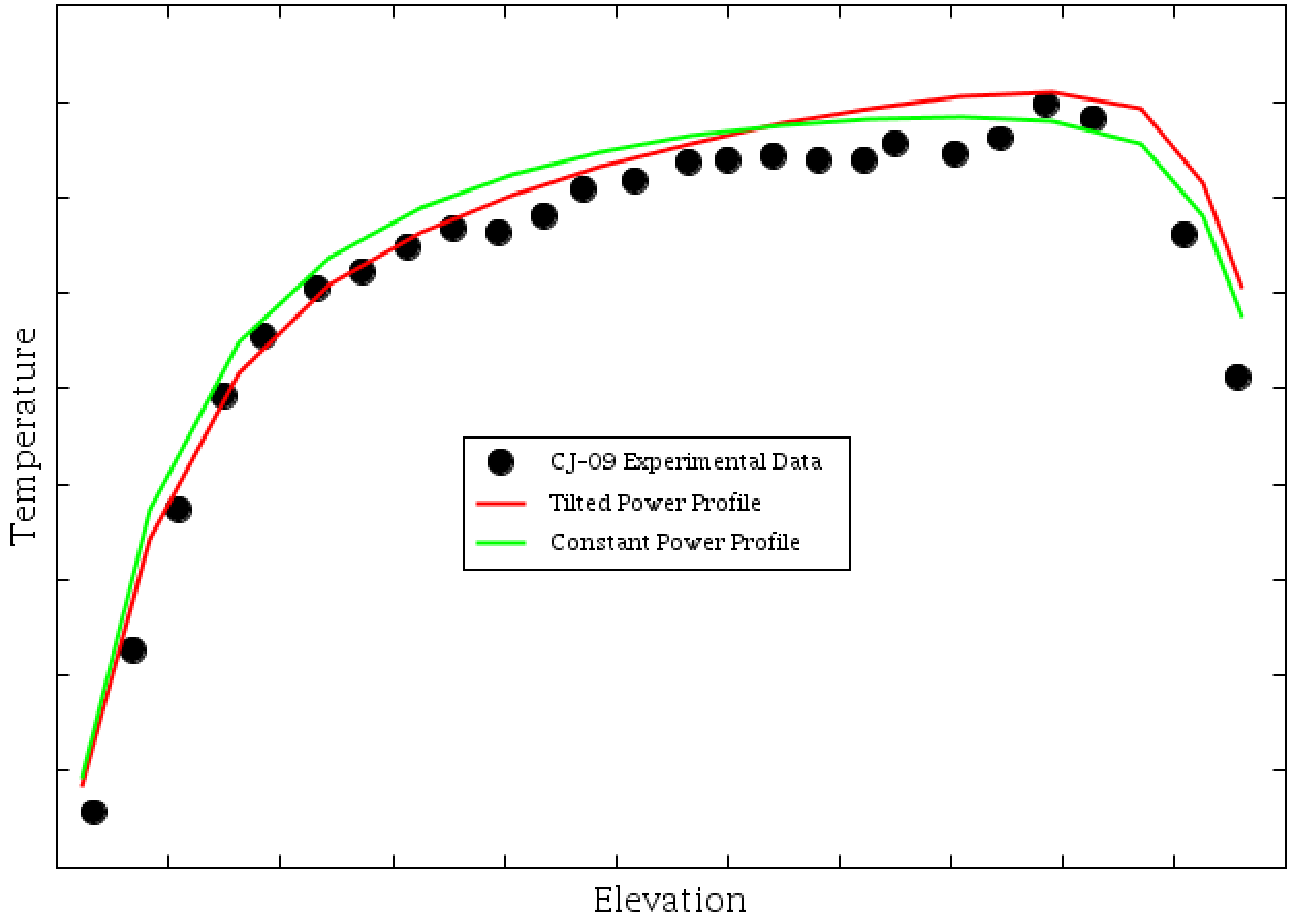
30 mol N_2
7.5 mol O_2
<1 mol H_2O
0.01 mol CO_2
0.4 mol Ar

Oxygen Outlet Concentration



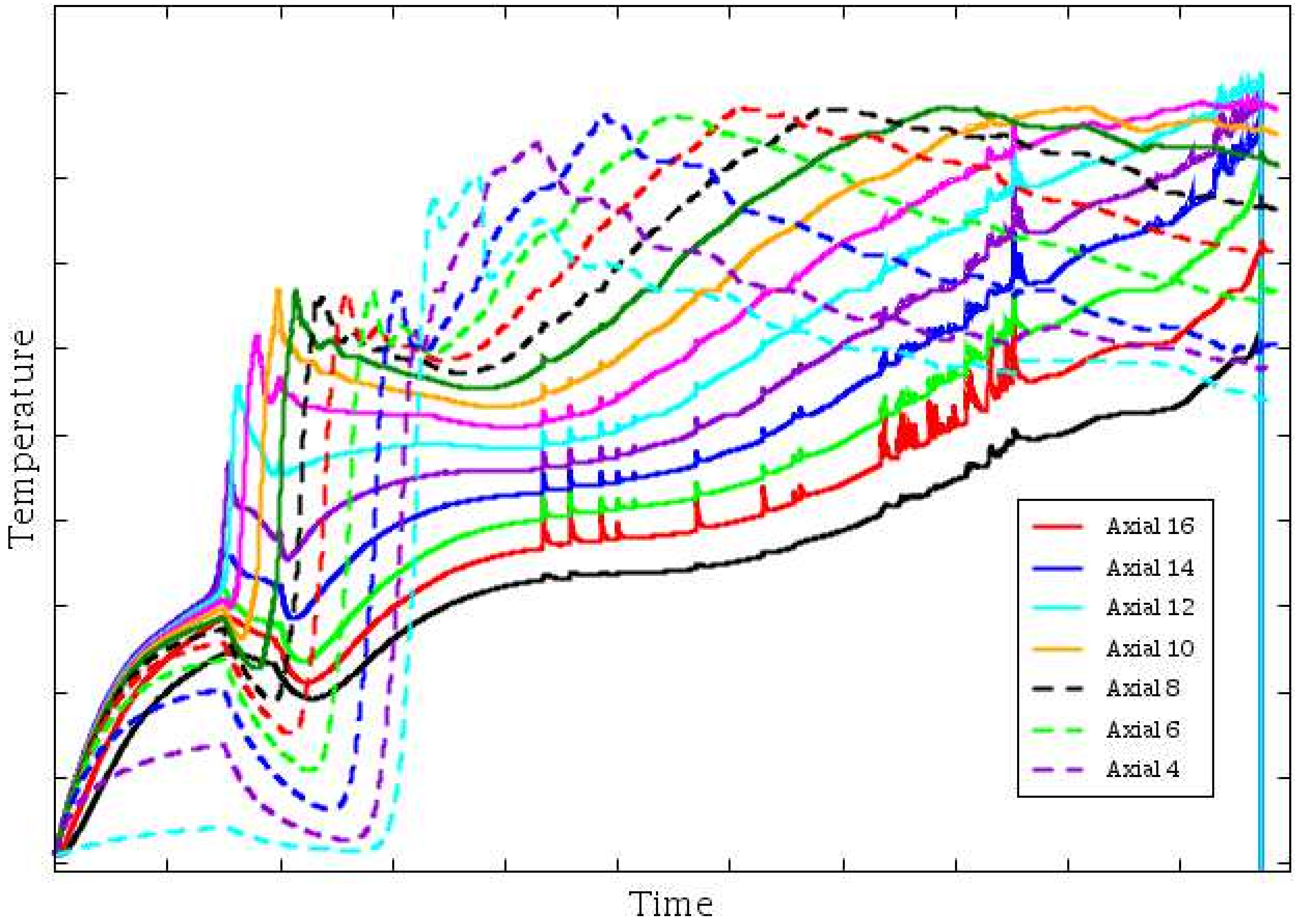
Oxygen partial pressure behaviour fits experimental data.
Later "oxygen recovery" during zirconium fire downward propagation is due to counter current flow of air from above.

Axial Temperature Profile

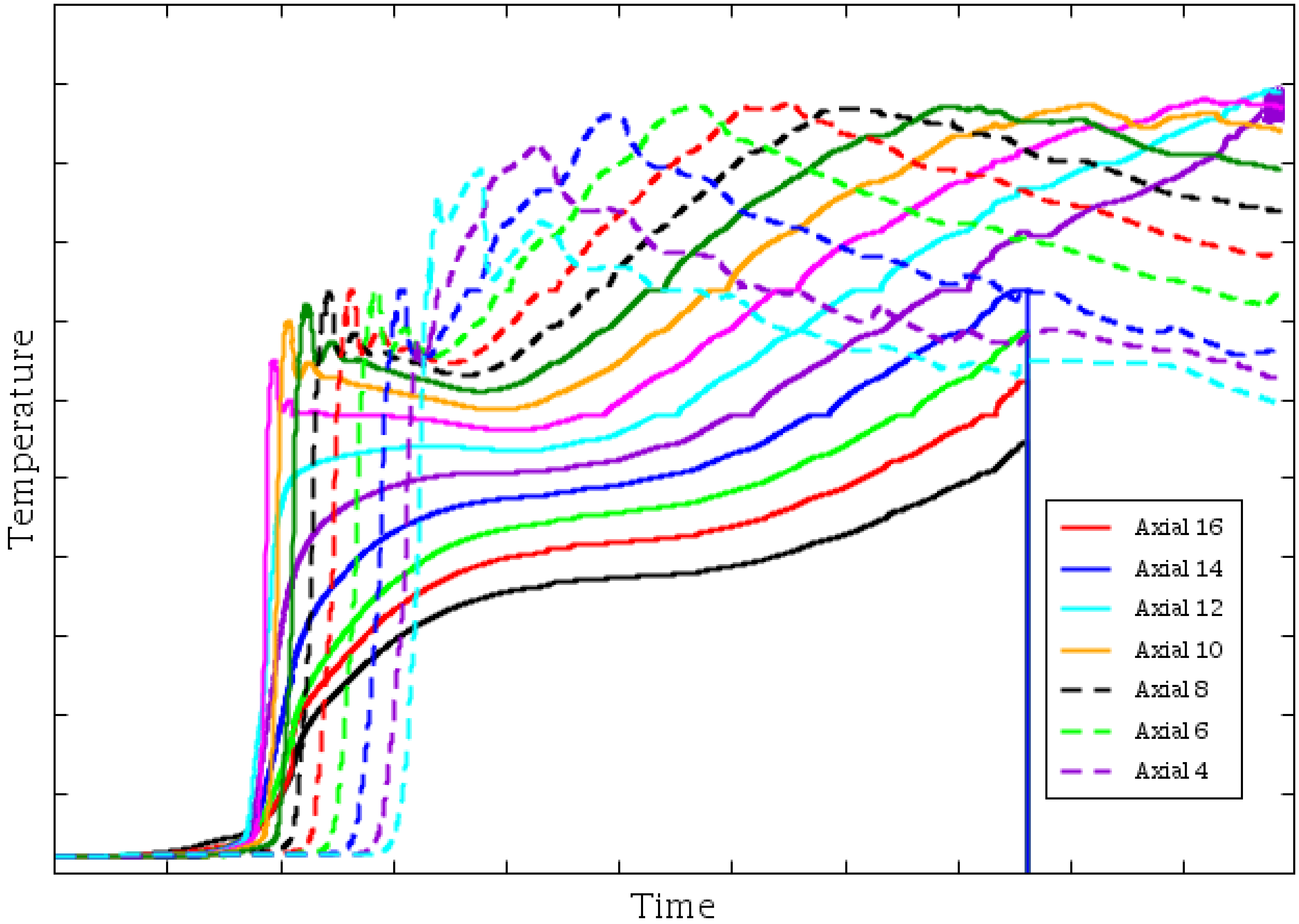


Tilted power profile gives better estimation of axial temperature profile shortly before ignition.

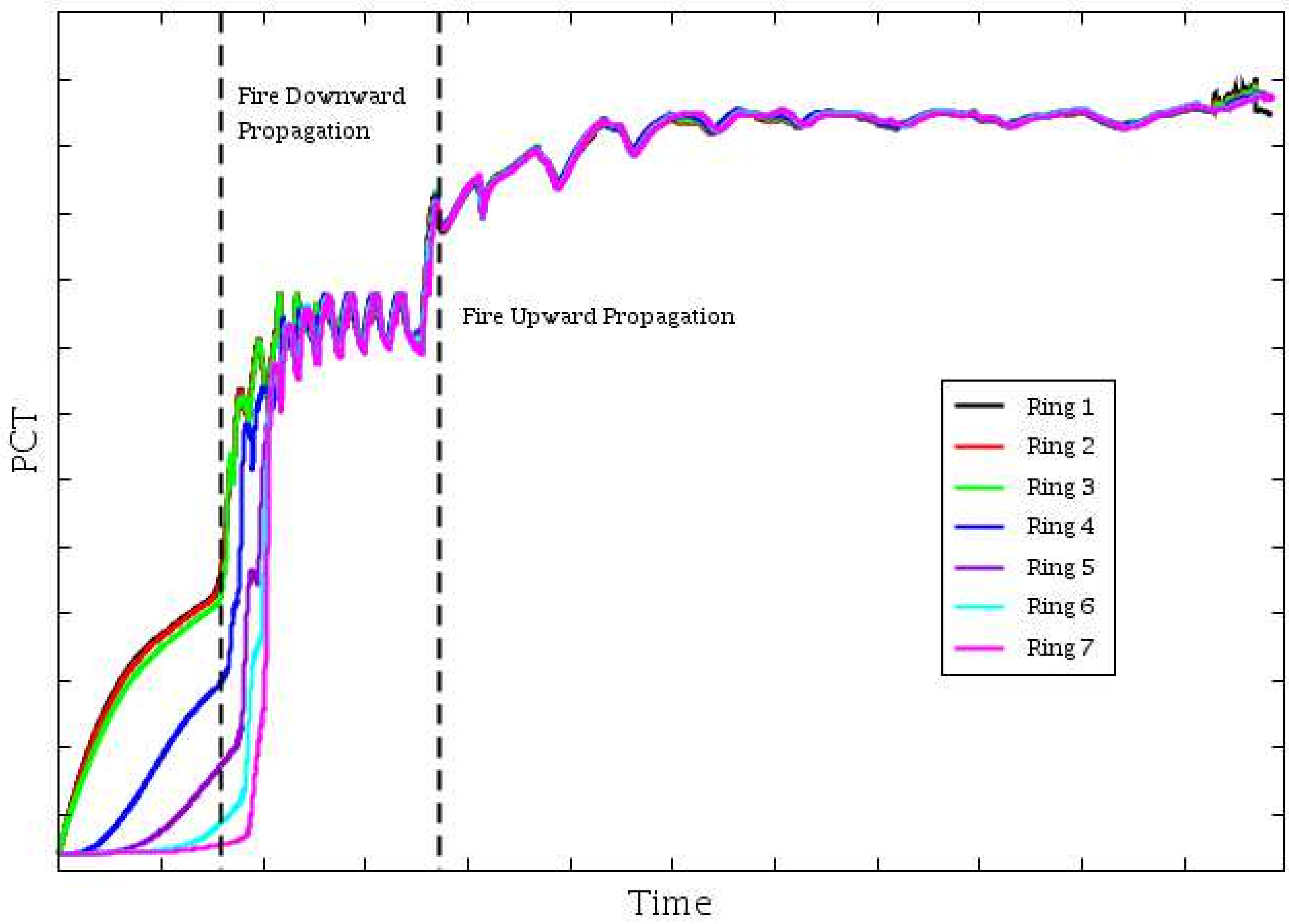
Central Temperature History



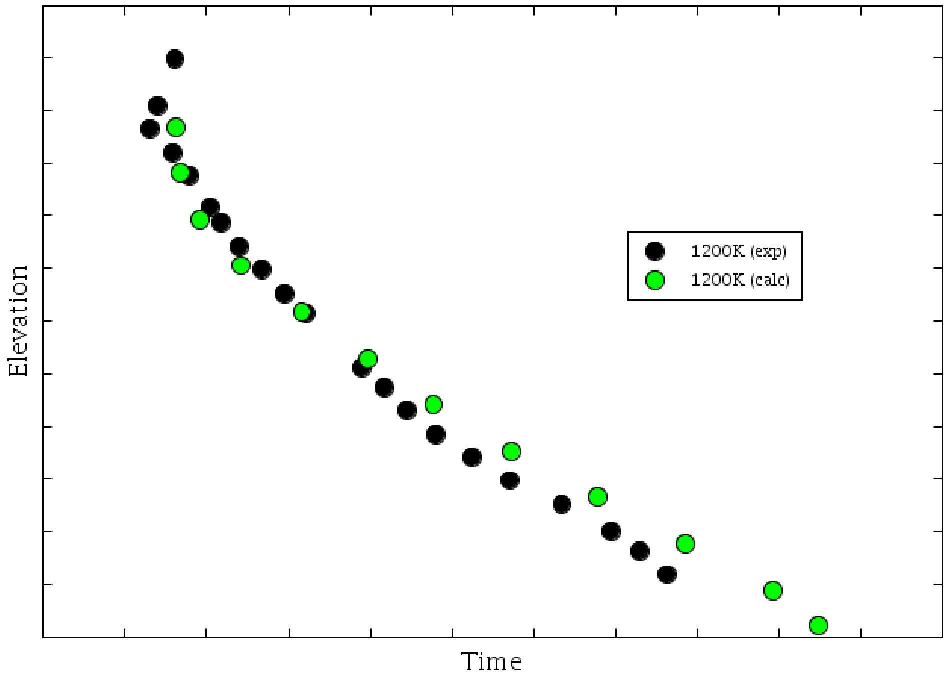
Peripheral Temperature History

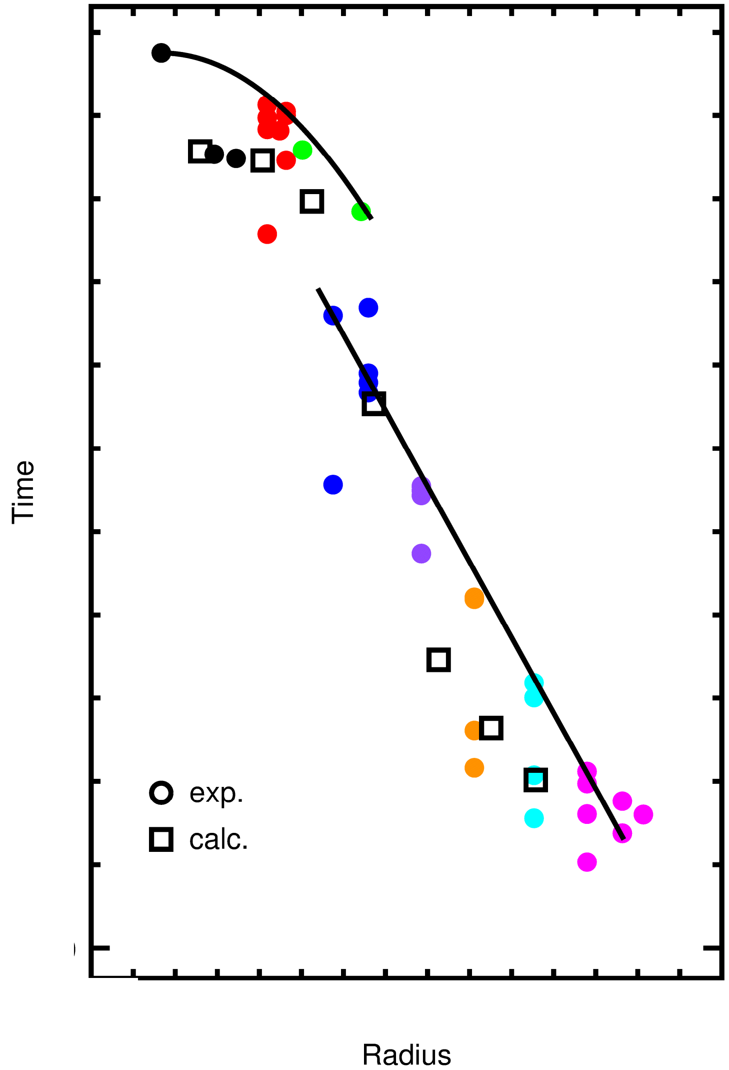


Peak Cladding Temperature History



Axial and Radial Fire Propagation

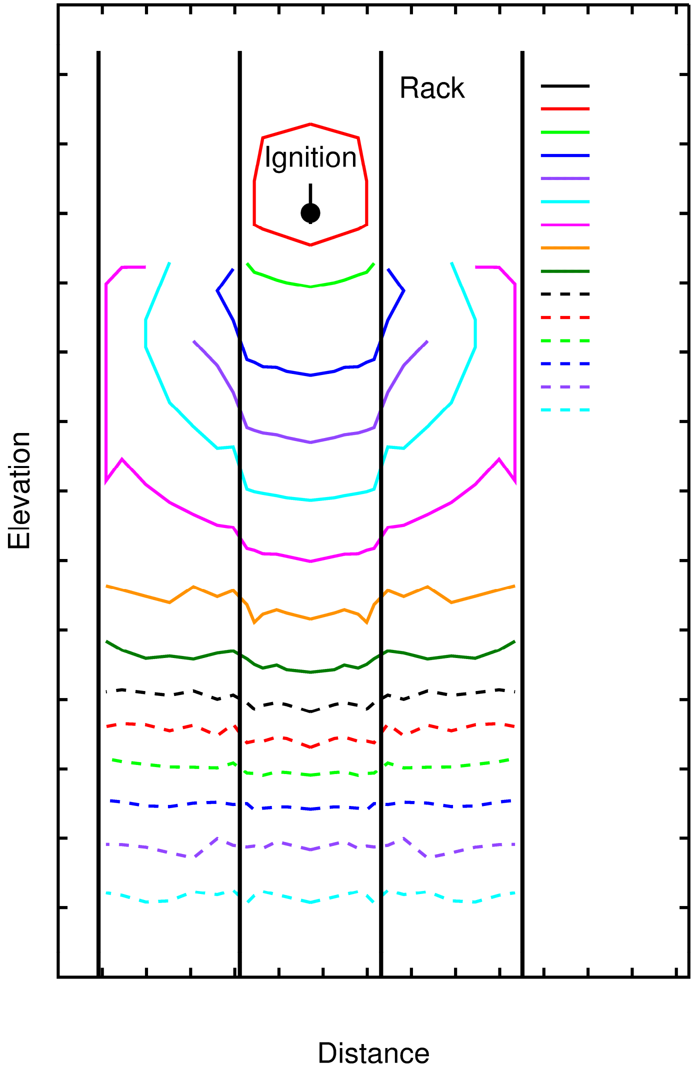




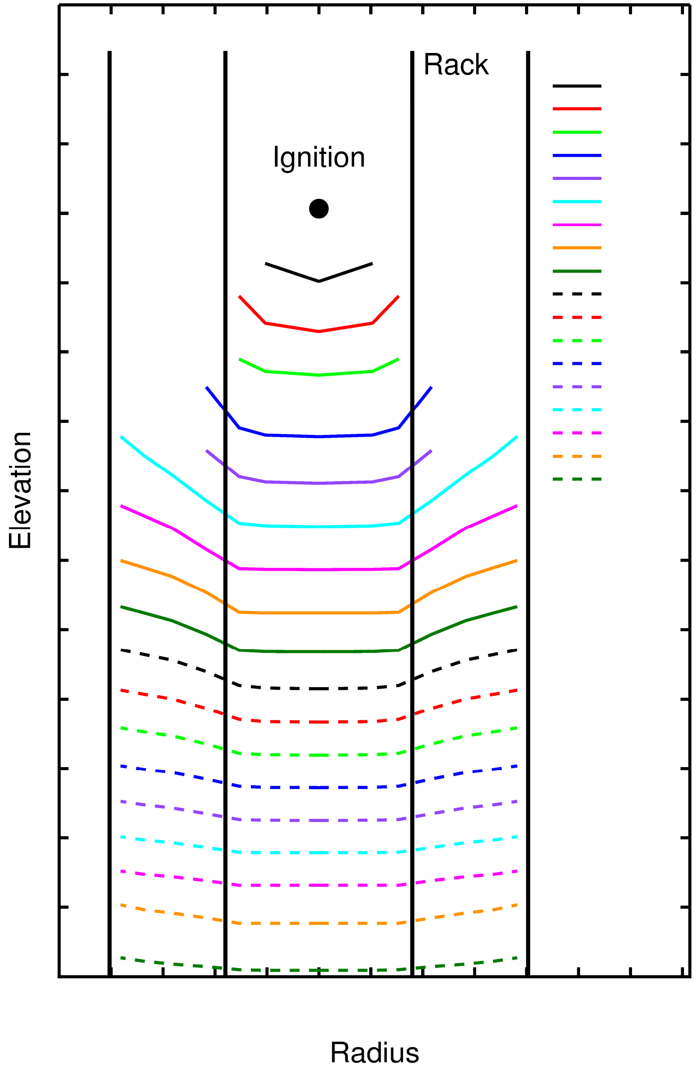
The axial and radial zirconium fire propagation is calculated in reasonable agreement with the measured data.

Axial and Radial Fire Propagation

Experiment



Calculation



Fire Downward Propagation

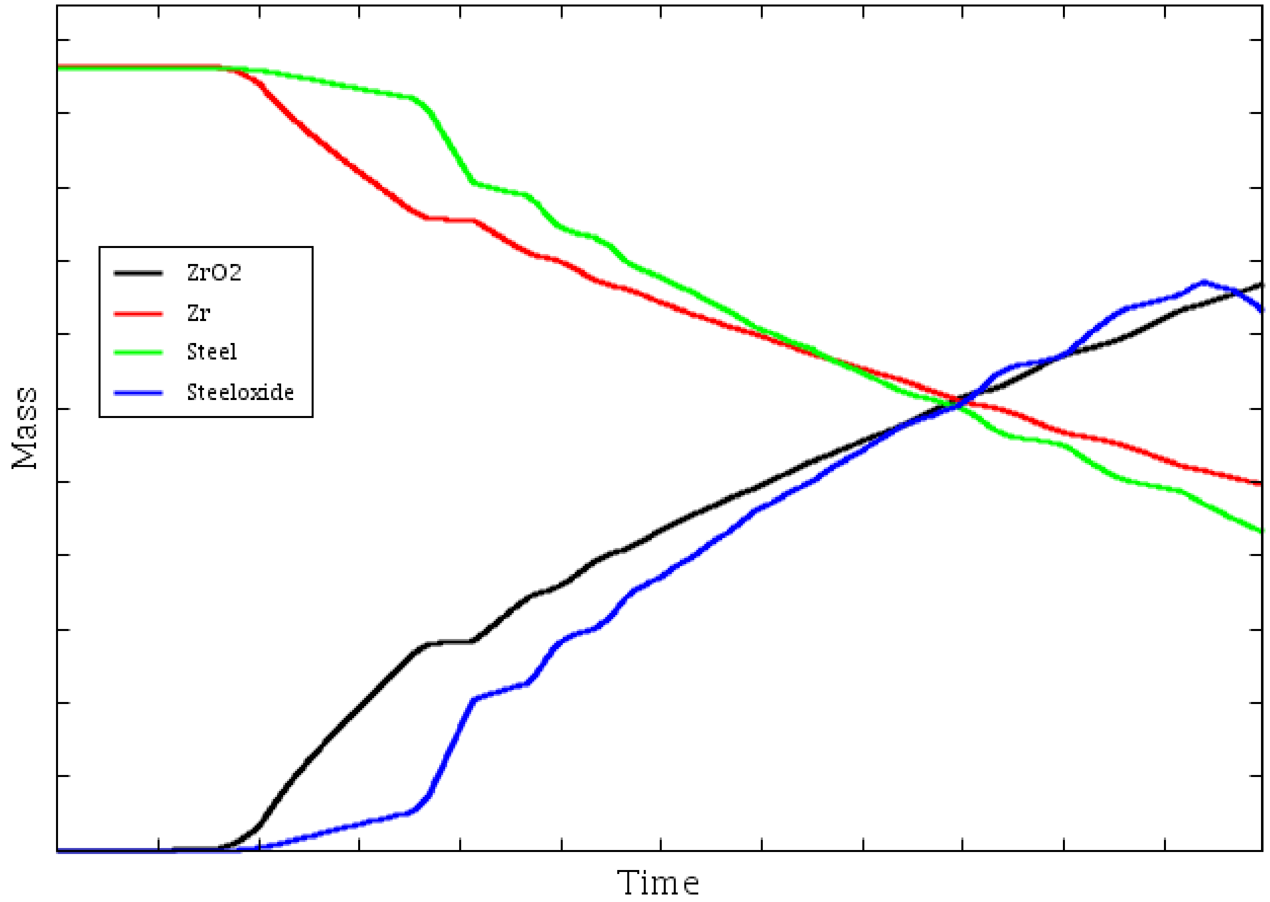
During the fire downward propagation there was oxygen starvation in the upper part of the facility.

About 20% of the zirconium was oxidized during this time.

The nitriding is not represented in MELCOR, which means an underestimation of heat generation at this time

Complete nitriding of the remaining zirconium in the oxygen starved region occurred with less than 50% of the nitrogen being consumed

Zirconium and Steel Oxidation



During the downward fire propagation almost only zirconium was oxidized.
During the upward fire propagation also steel was oxidized in the calculation.

Fire Upward Propagation

During the upward propagation of the fire front the oxygen was oxidizing the ZrN and releasing the nitrogen through the outlet, where it was measured.

Also the remaining steel was completly oxidized during this time. The fire was burning for about three more days, until all the metall was oxidized.

Conclusions

The MELCOR code calculation gives a rather good estimation with the meassurements even if there are some missing models.

It is not only the nitriding reaction which increases the heat input during downward propagation of the zirconium fire but also the consumption of nitrogen. Convective heat loss was reduced by almost 1/3 due to nitrogen consumption during downward propagation.

Modeling of the SFP phase II experiment lies partially outside the scope of the standard MELCOR heat transfer model.

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Thank you for your attention