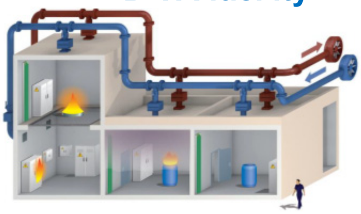
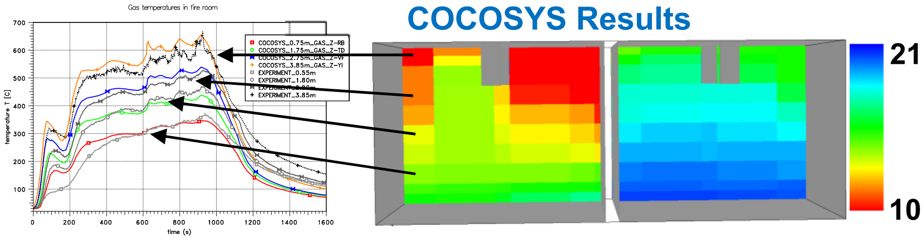
COCOSYS applicability for predicting fires in NPPs

W. Klein-Heßling, M. Pelzer (GRS)

Validation calculations against OECD PRISME fire experiments in the DIVA facility of IRSN in Cadarache [1] have proven the general applicability of COCOSYS for the simulation of thermodynamic processes relevant in case of combustion in a confined compartment [2]:

DIVA facility

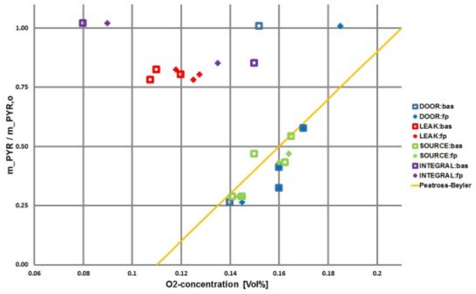




Atmospheric temperature *Oxygen concentration*

Prediction of the pyrolysis rate

Crucial point for best-estimate fire simulations is the prediction of the pyrolysis rate (i.e. rate of vaporized fuel mass), which has a large effect on the heat released and hence the entire processes in the fire compartment. Typically, the fire source's pyrolysis rate in open atmosphere conditions is known. In a confined compartment, the pyrolysis rate develops differently mainly due to two effects:



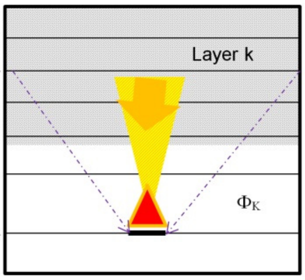
Oxygen depletion

Empirical correlation from Peatross and Beyler [3]

$$\dot{m}''_{PYR} = \dot{m}''_{PYR,o} \cdot [0.1 \cdot c_{O2} - 1.1]$$

Pyrolysis rate in compartment — Pyrolysis rate in open atmosphere — Oxygen concentration

Confirmed in PRISME experiments with "cold" gas temperature in the fire compartment (< 200 - 250 °C)



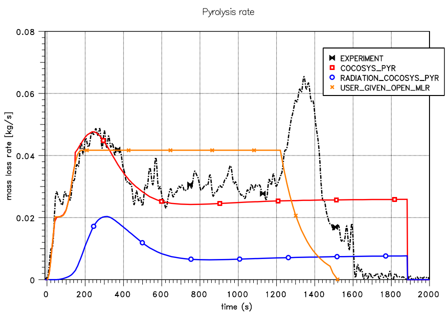
Radiation feedback

Radiation exchange between each gas layer and fuel surface:

$$\dot{Q}_{Rad,k} = \Phi_k \cdot \sigma \cdot A_{pan} \cdot \varepsilon_{fuel} \cdot \varepsilon_{soot,k} \cdot (1 - A_{ABSORB}) \cdot (T_k^4 - T_{evap}^4)$$

- Emissivity of gas layers depending on soot concentration
- Absorption in layers in between acc. to Lambert-Beer-Law
- Additional pyrolysis rate $\dot{m}''_{PYR,rad} = \frac{\sum_k \dot{Q}_{Rad,k}}{\Delta H_V \cdot A_{pan}}$

Validation on PRISME INTEGRAL D4 [1] [2]



Isolated walls → gas temperatures exceed 600°C

- Given pyrolysis rate from open atmosphere
- COCOSYS predicted pyrolysis rate
- Contribution: Radiation Feedback (~ 33 %)
- Measured pyrolysis rate - *exceeds open atmosphere rate in the beginning due to radiation feedback.*

[1] L. Audouin et al.: "OECD PRISME project: Fires in confined and ventilated nuclear-type multi-compartments - Overview and Main Experimental Results", Fire Safety Journal, to be published 2012
[2] M. Pelzer, W. Klein-Heßling: "Validation of COCOSYS pyrolysis models on OECD PRISME fire experiments", Fire Safety Journal, to be published 2012
[3] M. J. Peatross, C. L. Beyler: "Ventilation effects on compartment fire characterization", International Association for Fire Safety Science (Ed.), Int.Symposium on Fire Science, Vol. 5., 1997, 403-414

GRS – W. Klein-Heßling
Schwertnergasse 1, D-50667 Köln
Walter.Klein-Hessling@grs.de