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Convection influence on the modelisation of a fire test on a radioactive material transport package

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Context

The protection and transportation of radioactive material by road, train or boat require nuclear transport packages. Therefore, the packages containing the most dangerous materials have to comply with several reglementary tests, including a 30 minutes 800 °C fire test. This test may be performed on a package mock-up, or numerically, with conditions representative of the fire (surface emissivity, ambient temperature, coefficient of convection ...).

The value of 10 W.m⁻².K⁻¹ for the coefficient of forced convection during the fire is given by the IAEA regulation guide No. SSG-26. Scientific literature and recent research [1] suggest that this value could be scaled up. IRSN performed calculations on a dummy transport package, with a high and a moderate thermal power content in order to quantify the coefficient influence during the fire.

The package model

The package is a 7 m high and 2.5 m diameter cylinder, with several layers, as detailed on figure 1. The cavity contains high temperature radioactive material. The containment is completed by a primary and a secondary lid, equipped with elastomer gaskets.

The thermal problem is meshed with the Cast3M 3D code and solved with the ThermX-Protée code [2].

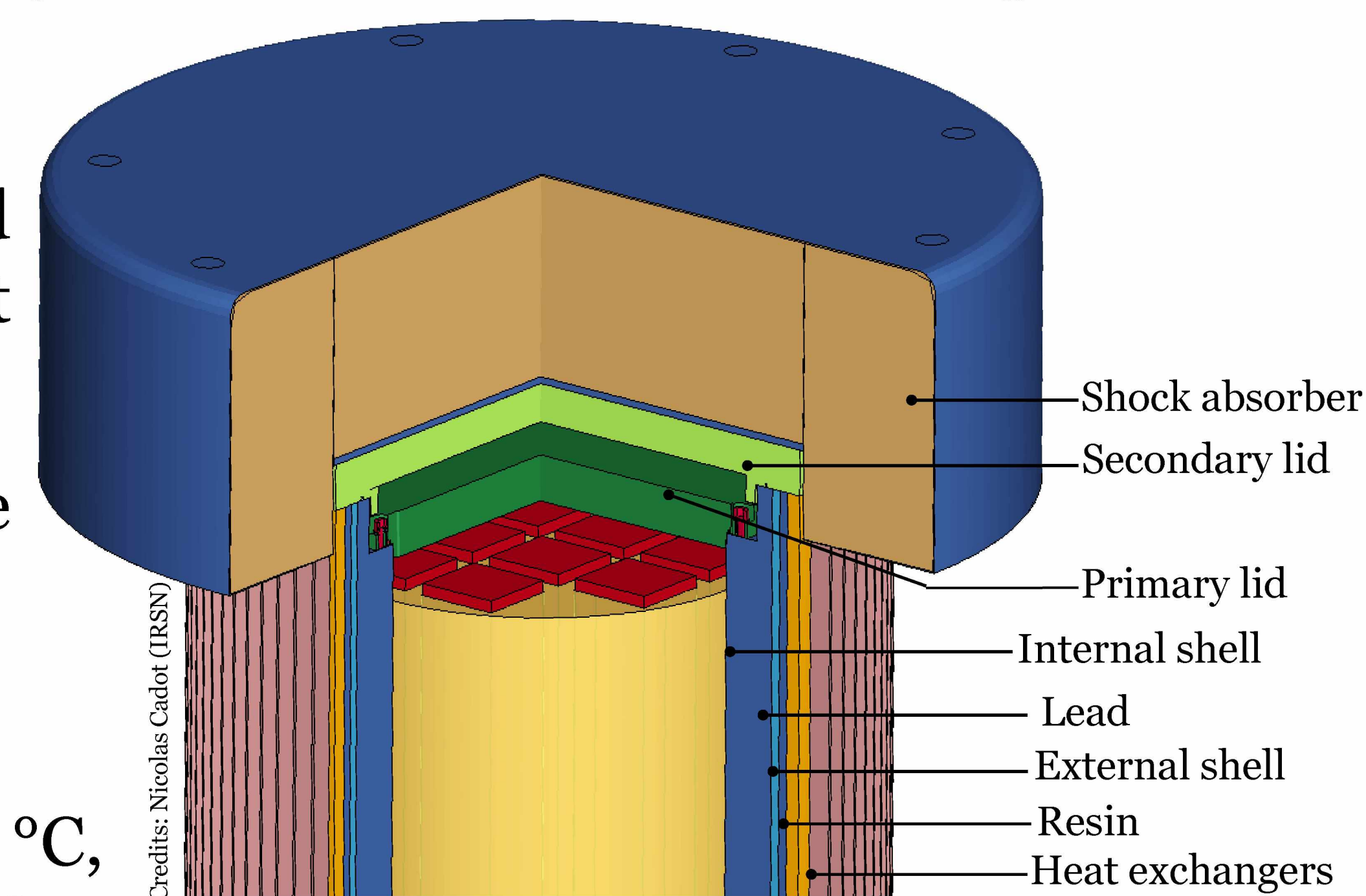


Fig. 1: Simplified representation of the package

Calculation – Cooling phase results

During the fire, the temperature of the external components increases by 250 to 400 °C, unlike the temperatures of the other components, which temperatures remain quite stable.

During the cooling phase, the endothermic material (resin) releases the heat absorbed during the fire. The sensitive elements reach their highest temperatures during this phase.

The figure 2 shows, for a range from 0 (no convection) to 100 W.m⁻².K⁻¹ of the coefficient of convection, the maximal values reached by the temperatures on the package surface, inside the package (basket) and on the main containment gasket, after the cooling phase following the fire, for a package equipped with heat exchangers or not on its surface.

The figure 3 shows the impact of the contents thermal power variation on the temperatures of the package.

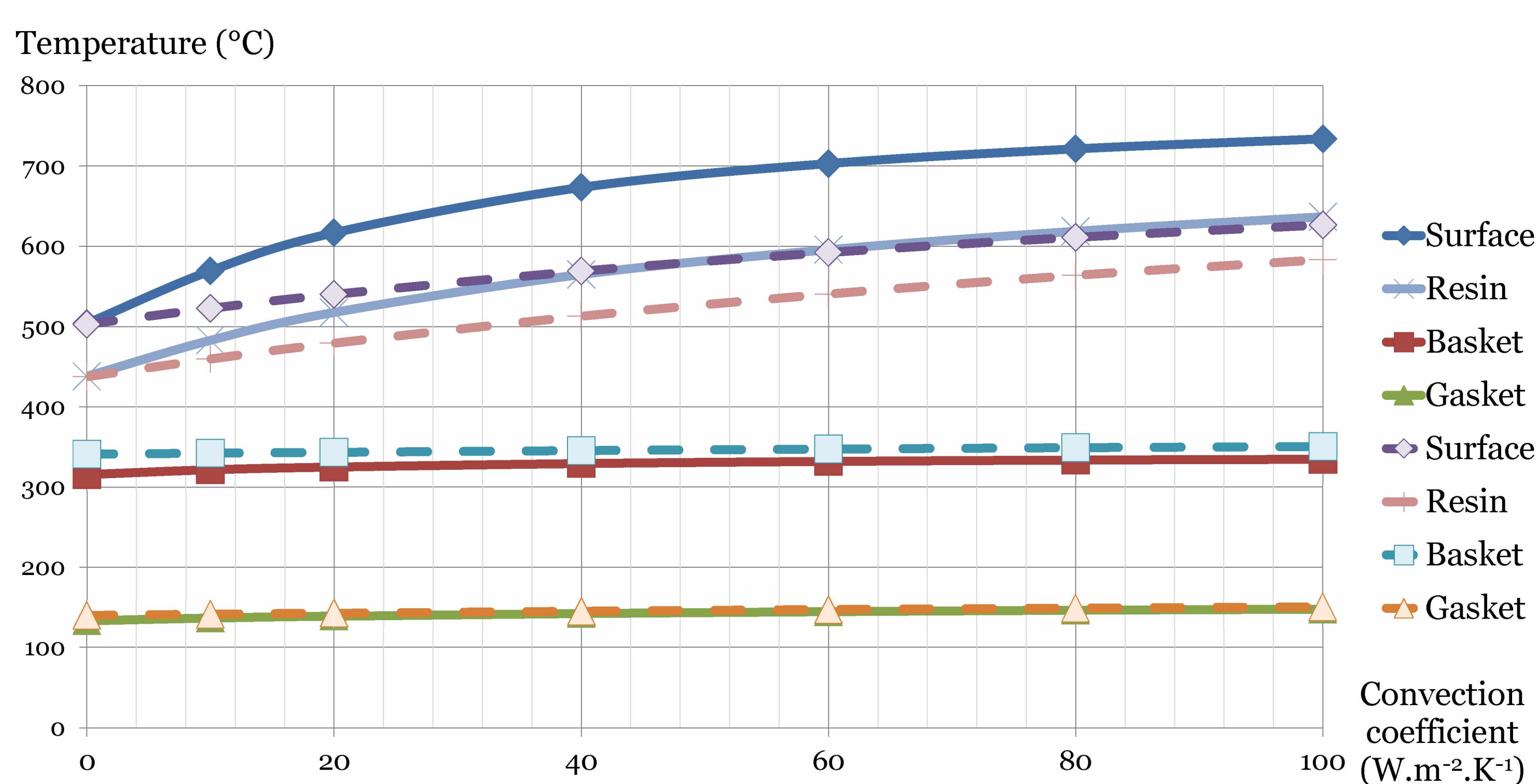


Fig. 2: Temperatures of the package equipped (plain lines) or not (dashed lines) with heat exchangers after the cooling phase

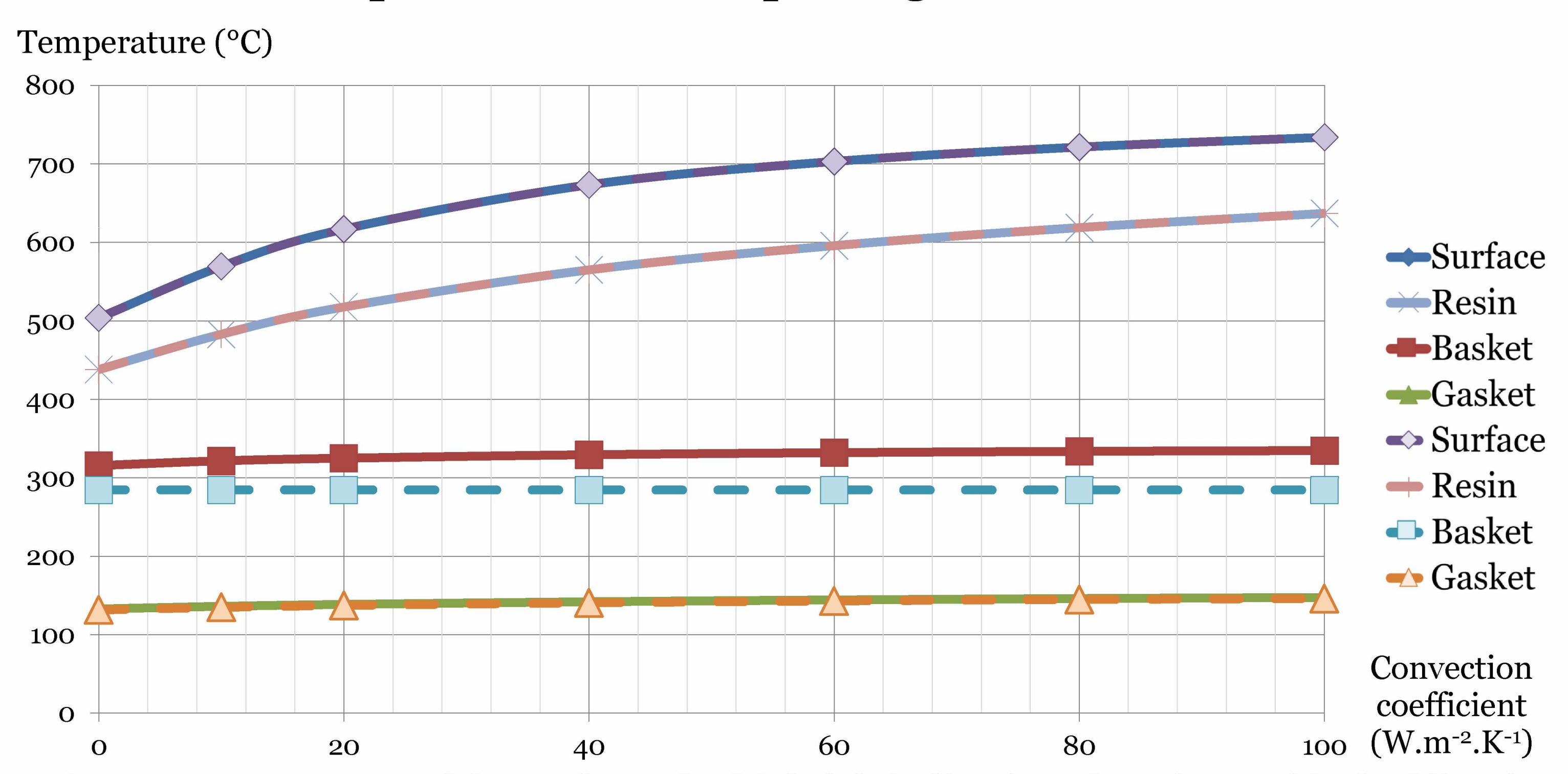


Fig. 3: Temperatures of the package for high (plain lines) and moderate (dashed lines) thermal power content after the cooling phase

Both figures indicate that :

- the increase of the value of the convection coefficient during the regulatory fire has moderate to little effect on the temperature of the internal components, such as the elastomer gaskets which increase of a maximum of 15 °C ;
- the variation of the surface exchanges of the package or its internal thermal power has little to no effect on the temperature of the internal components as well, mostly on the basket.

Conclusion

For a package with high inertia (due to the presence of several layers, one of which being an endothermic material), the increase of the convection coefficient during the fire phase has moderate to little effect on the temperature reached by the sensitive components, such as the containment gaskets.

The inertia of the package, as well as the codes used for calculation, induce many uncertainties on the results. The next step would be to consider calculation with a package of lesser inertia.

[1] M. Feldkamp, T. Quercetti, F. Wille; Fire reference test for IAEA Package thermal testing in a propane gas fire test facility, PATRAM 2019, New Orleans, LA, USA.

[2] ThermX-Protée code, CEA-IRSN, 2009 version.