

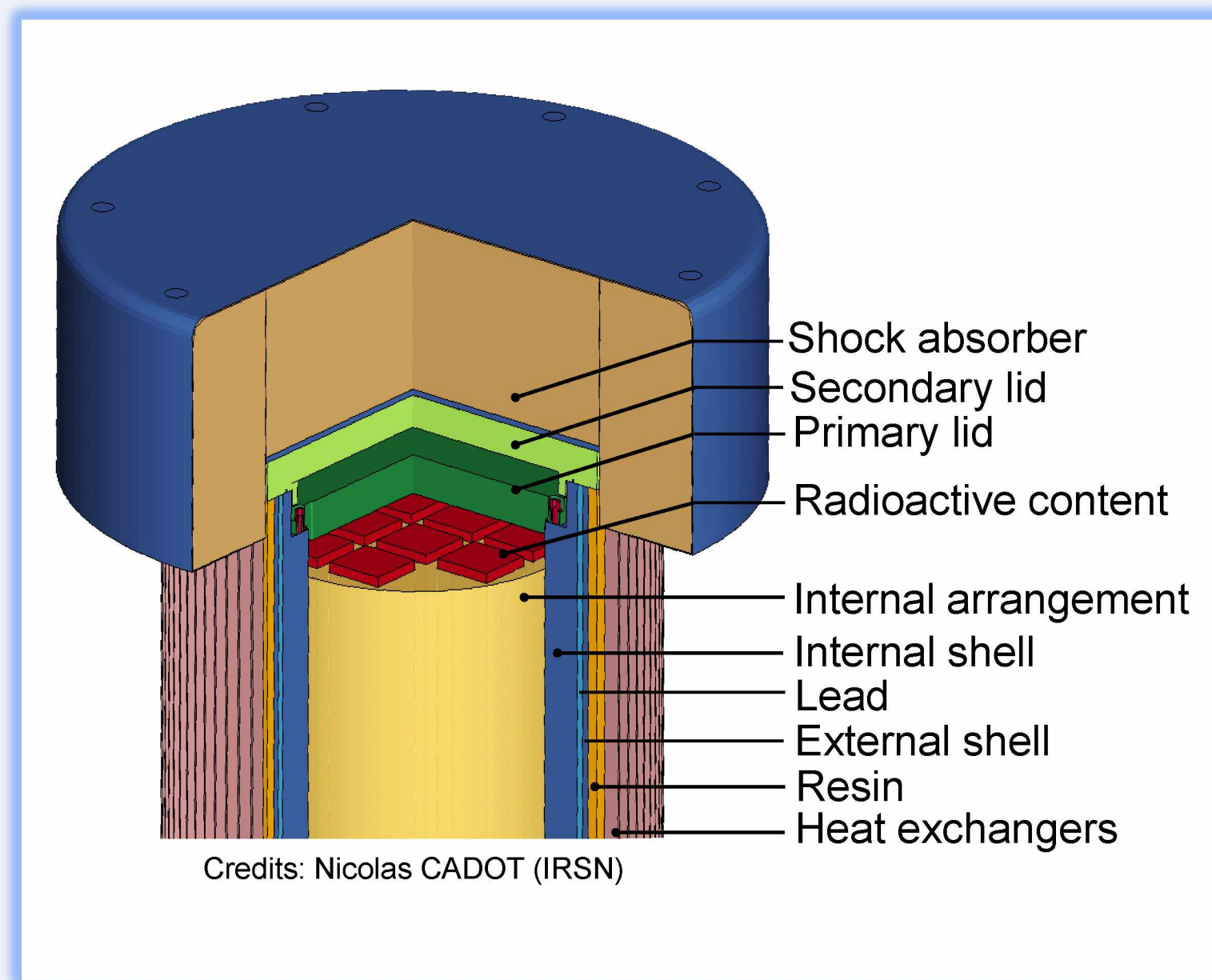
INFLUENCE OF THE CONVECTION COEFFICIENT ON THE NUMERICAL MODELING OF A FIRE TEST ON A NUCLEAR TRANSPORT PACKAGE

Norma Verbrugghe, Gaël Desroches, Baptiste Louis, Bruno Tissot, Florence Gauthier

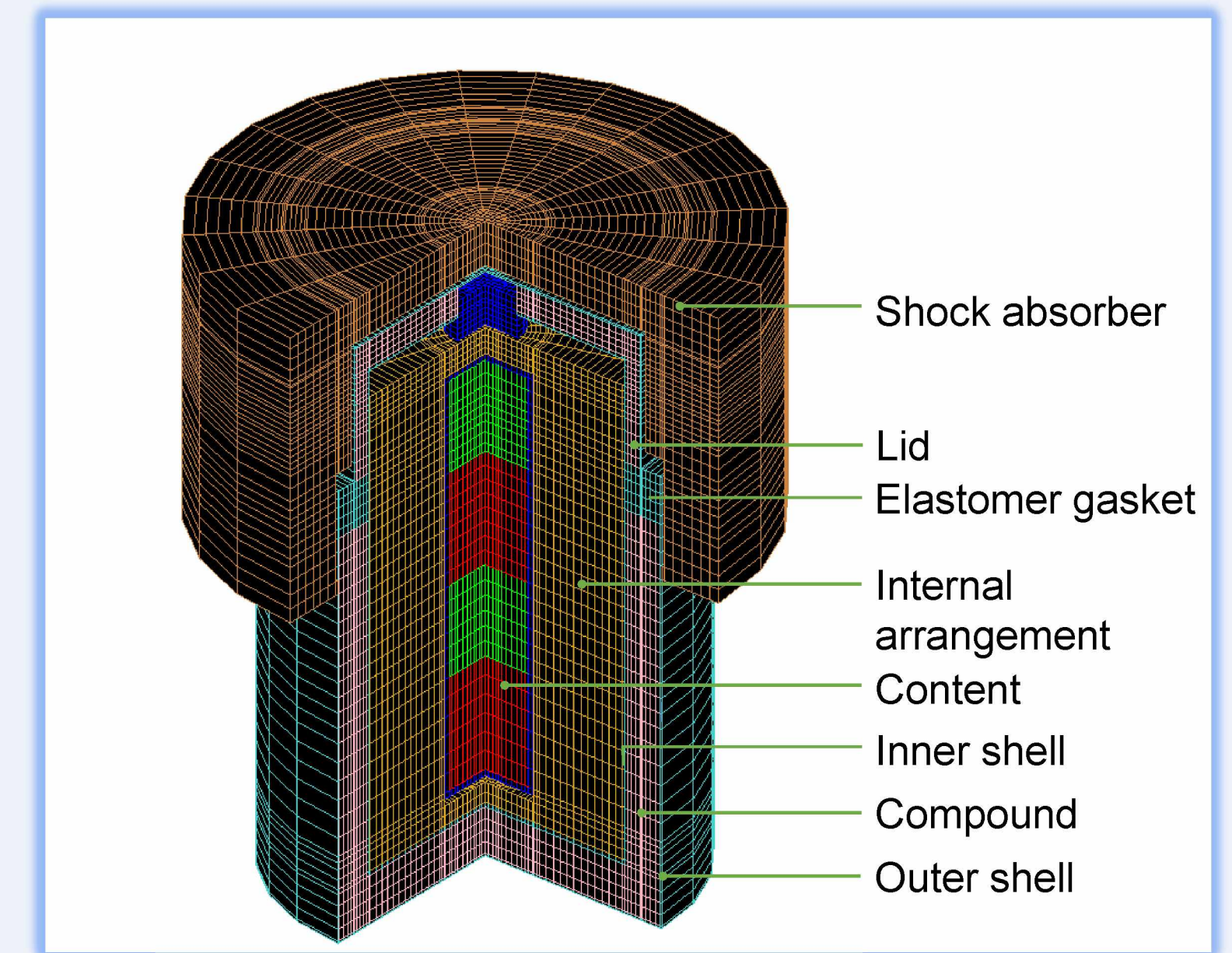
Context

The IAEA SSR-6 regulations require that a type B or fissile package should be submitted to a specified thermal test to demonstrate that its safety functions are maintained in accident conditions of transport. Recent research based on real fire tests suggests that the convection coefficient value may be higher than the one recommended by the IAEA guidelines No. SSG-26 for the regulatory fire test, i.e., 10 W.m⁻².K⁻¹. Ultimately, does the value of the convection coefficient affect the temperature of the sensitive components of the package when subjected to the regulatory fire test? IRSN performed numerical calculations with CAST3M/ThermX-Protee to study the influence of the convection coefficient during the fire test on two French type B package models.

The package models



First model	Characteristics	Second model
7 m / 2.5 m	Height / diameter	1 m / 0.9 m
≈ 50 kW	Maximal thermal power	≈ 100 W
Heat exchangers	External surface	No heat exchangers
Multiple layers	Structure	3 layers
Fuel assemblies	Contents	U or Pu powder



Outcome

First model

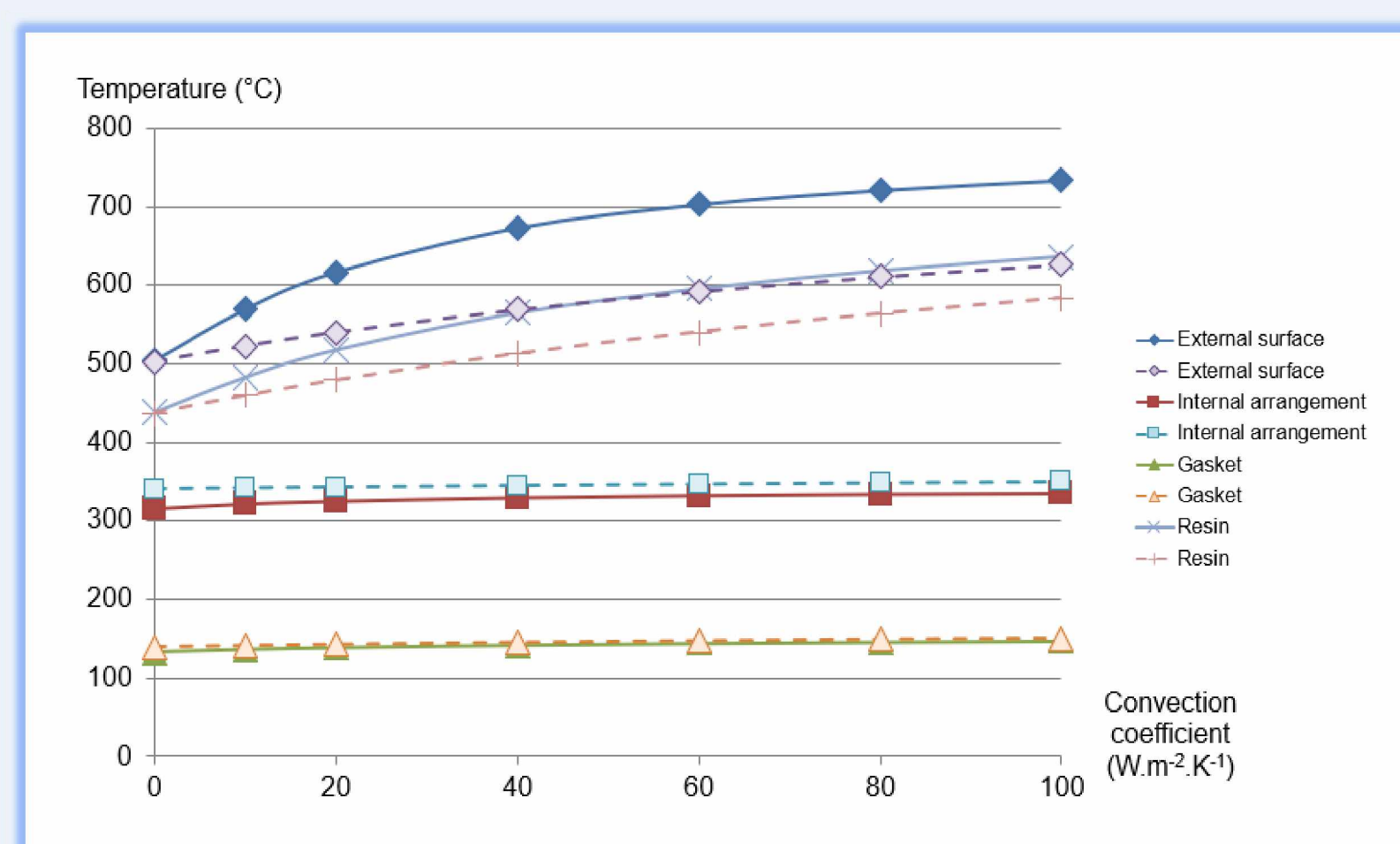


Figure 1. Maximal temperature of the (undamaged) package equipped (plain lines) or not (dashed lines) with heat exchangers, obtained during the cooling phase

Base study: package equipped with heat exchangers, high thermal power

Sensitivity studies: no heat exchangers or moderate thermal power

⇒ Moderate to little effect of the increase of the value of the convection coefficient during the regulatory fire on the temperature of the inner components

⇒ Little to no effect of the variation of the exchange surface or of the internal thermal power on the temperature of the inner components

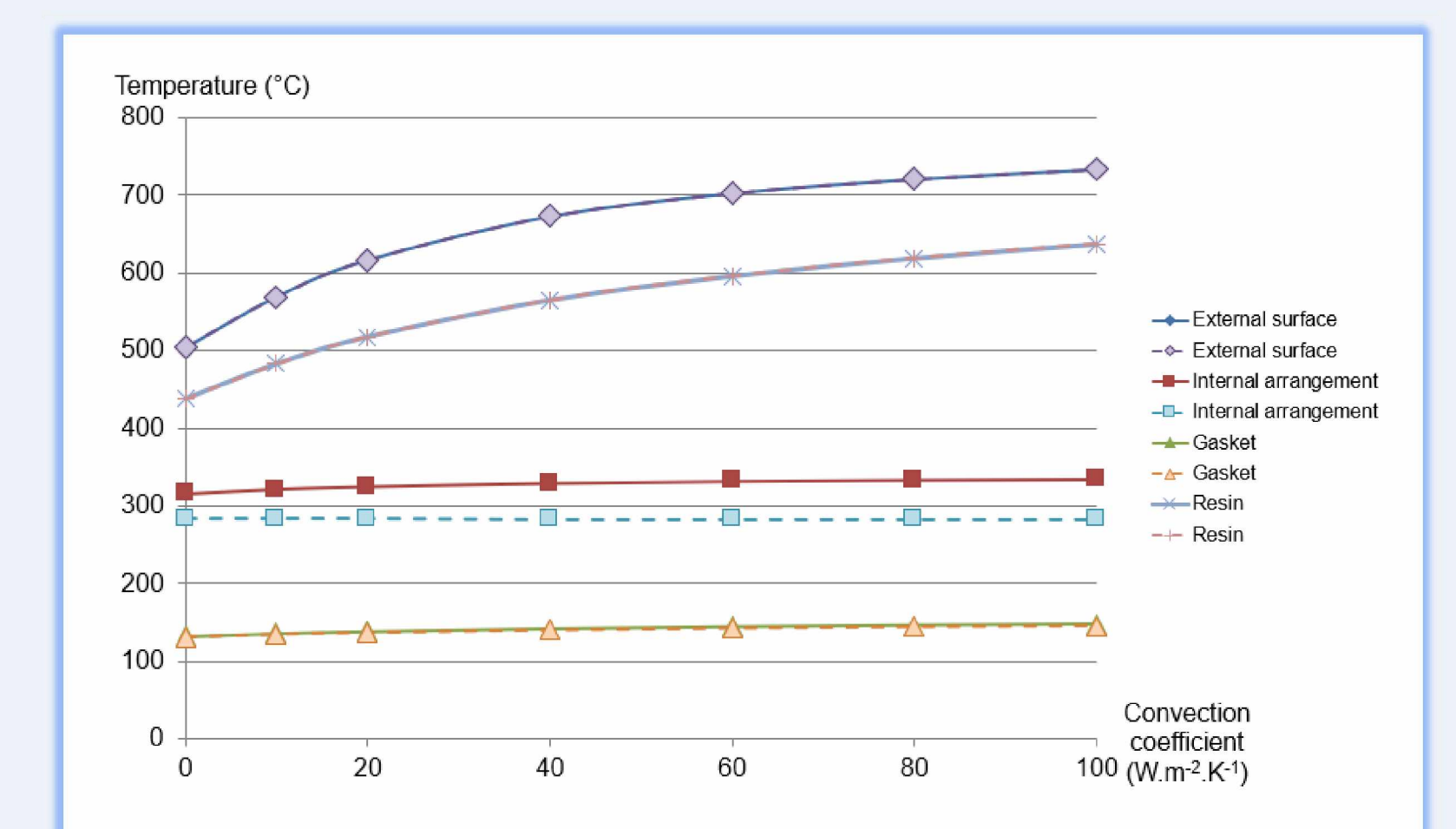


Figure 2. Maximal temperature of the (undamaged) package for high (plain lines) or moderate thermal power content (dashed lines), obtained during the cooling phase

Second model

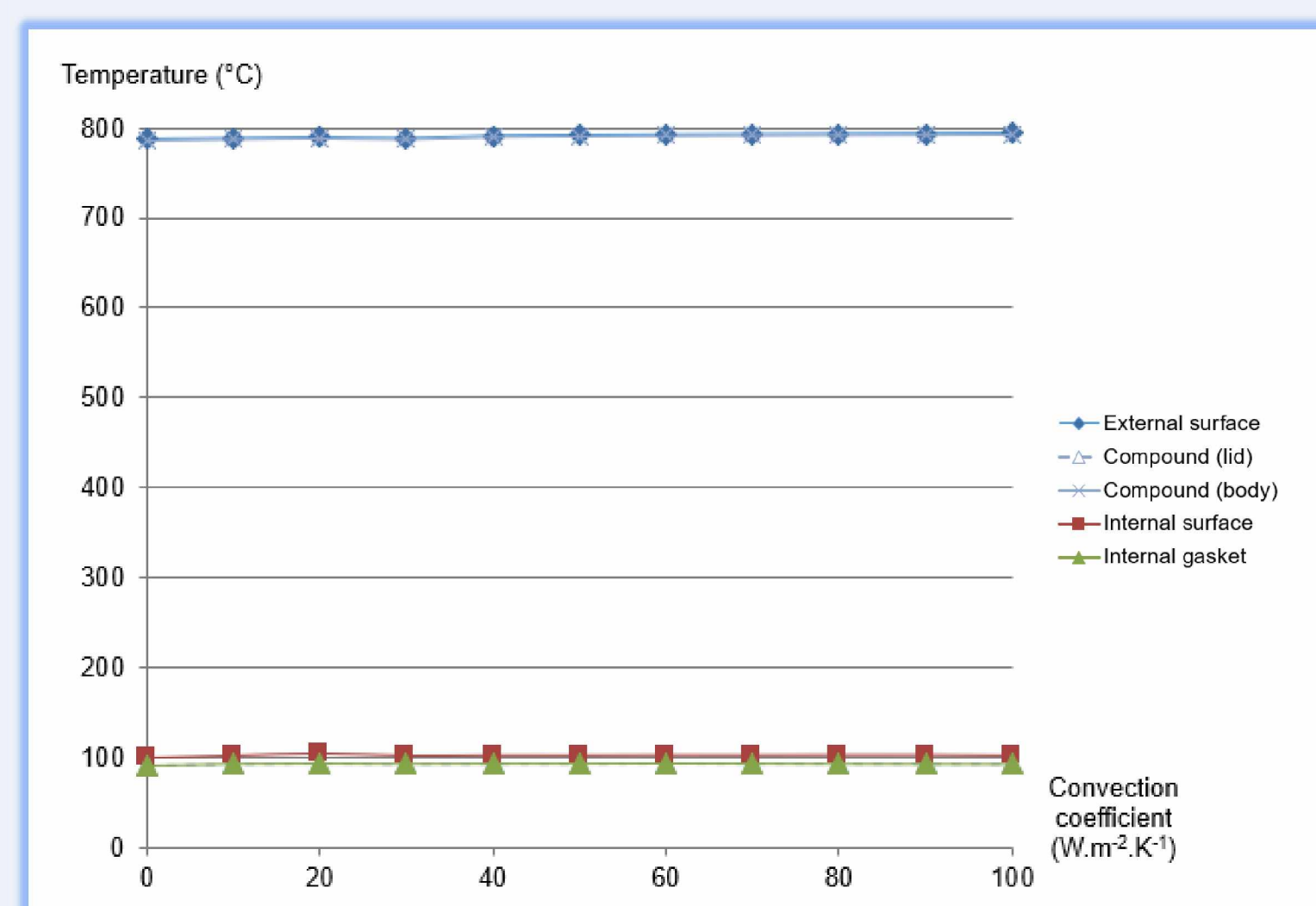
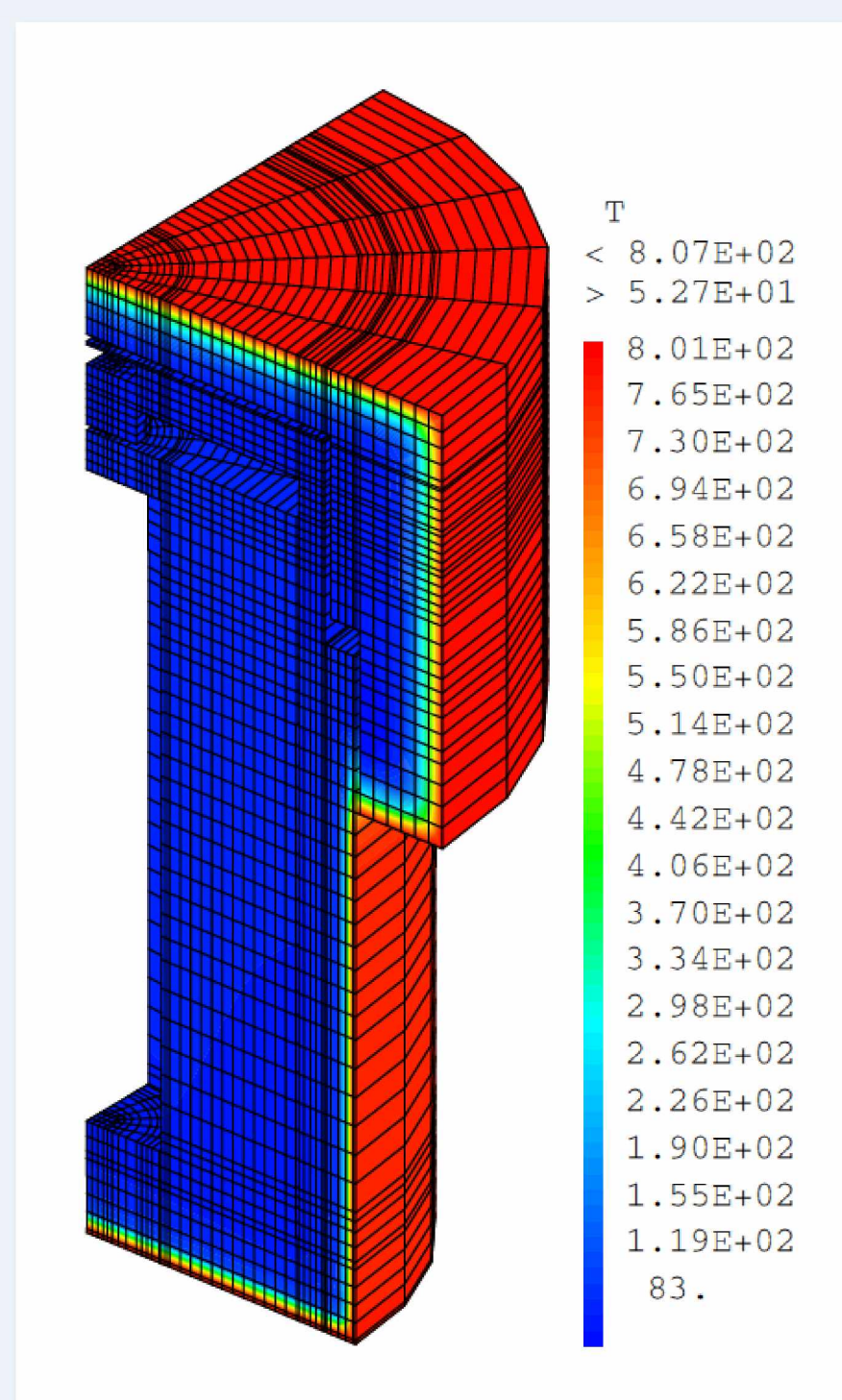


Figure 3. Maximal temperature of the low thermal power (undamaged) package during the cooling phase



Sensitivity studies

Crushed material:

$$\lambda = \left(\frac{e_0}{e}\right)^2 \times \lambda_0$$

λ, e : thermal conductivity and thickness of the crushed material

λ_0, e_0 : thermal conductivity and thickness of the initial material

For wood or compound, considering that the volume of the material is the initial volume

Convection coefficient:
h = 10 W.m⁻².K⁻¹

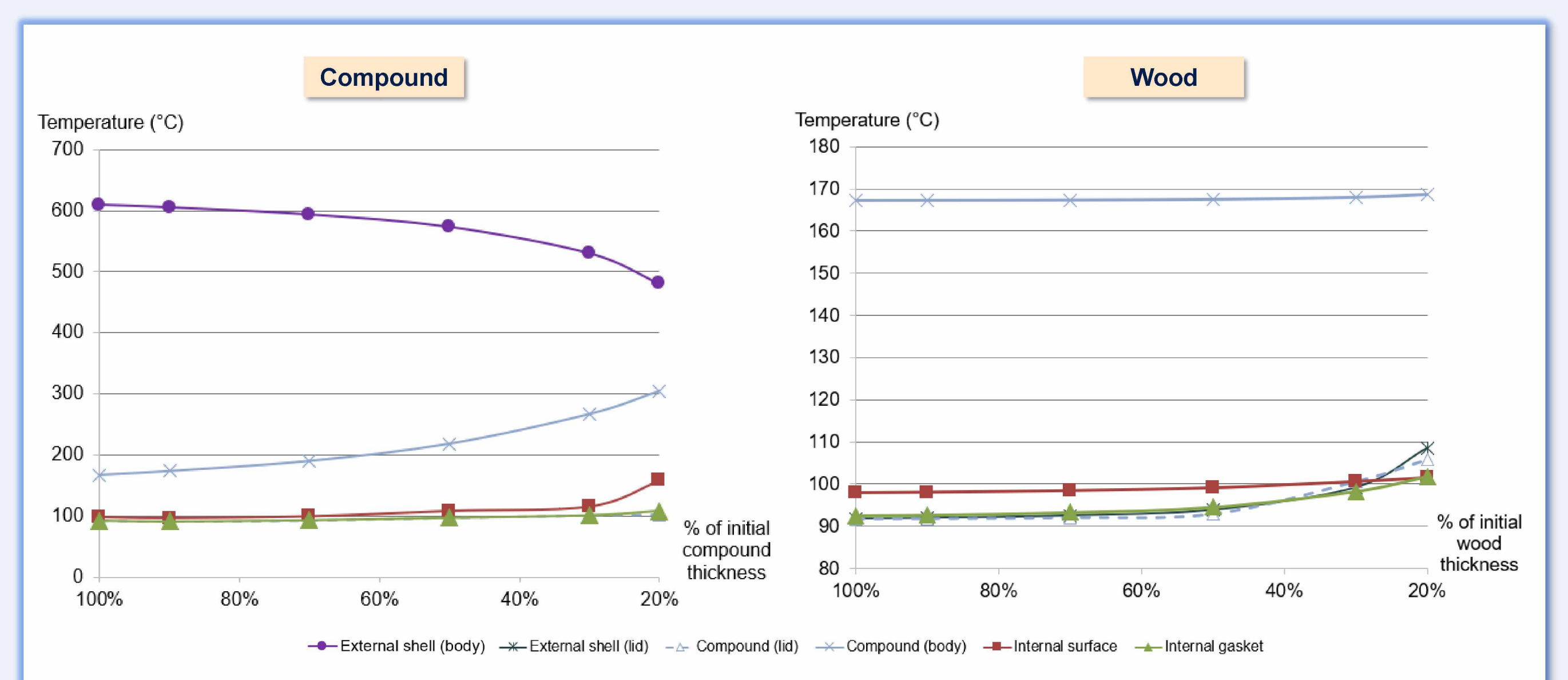


Figure 4. Average temperature of the low thermal power package during the cooling phase with variation of the insulation material thickness. Left: crushed compound. Right: crushed wood.

⇒ **Base study:** no effect of the variation of the convection coefficient during the fire test on the maximal temperature of the inner components during the cooling phase

⇒ **Sensitivity studies:** overall when less than 50 % of the initial thickness of the insulating materials remains, the temperature of the inner components starts to increase

Conclusions

From the calculations performed, it can be drawn that the increase of the convection coefficient during the fire test has moderate effect on the maximal temperature reached by the inner components, such as the containment gaskets.

The variation of the exchange surface of the package or of its internal thermal power has little effect on the maximal temperature of the inner components. The crushing of the insulating materials (compound and wood) has moderate effect on the temperature of the inner components of the package, until a threshold value.

The studied type B packages, while very different in design, both possess a high thermal inertia. Therefore, further sensitivity studies need to be performed as the thickness of the insulating materials – especially that remaining after an accidental impact – and the position of the sensitive components are two essential parameters.