IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

BEHAVIOUR OF A PACKAGE FOR TRANSPORT OF SPENT FUEL ASSEMBLIES EXPOSED TO BEYOND REGULATION FIRES

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Summary

- Context of the study
- Package design description and numerical modeling associated
- Thermal behaviour of the package submitted to fires
- Data for safety assessment in emergency situations
- Conclusions

Context of the study

Main activities of the French « *Institut de Radioprotection et de Sûreté Nucléaire* » (IRSN) in the radioactive materials transport safety

Technical assessment of the package designs safety reports according to IAEA requirements

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Provide supports to the French competent authorities for licensing of approved package designs

Participating in drawing up international recommendations under the aegis of IAEA

Provide safety assessment to the French competent authorities in emergency situations

Package design and numerical modeling

The present study concerns a new TN International package design, for transport of spent fuel assemblies, called TN®112

Package modeling

3 Dimensions model

Meshing of the half upper part of the package

¼ package section

79 281 elements

48 under parts

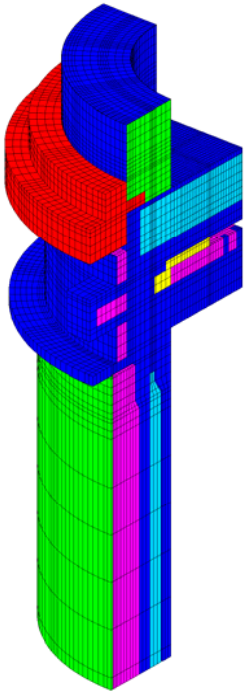
Thermal calculations

THERMX-PROTEE Software

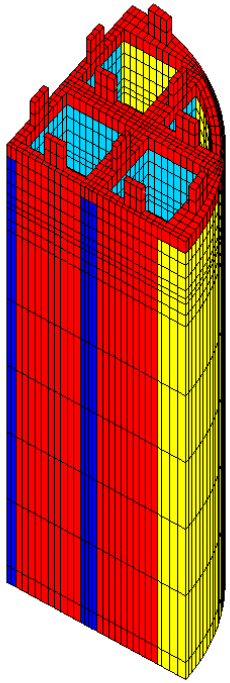
Modeling of the heat transfers in the endothermic materials

Package design and numerical modeling

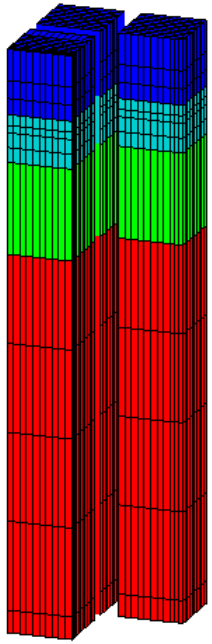
Packaging modeling



Basket modeling



Content modeling



End
L = 0.24 m

Part 3 (40 %)
L = 0.139 m

Part 2 (81 %)
L = 0.308 m

Part 1 (110 %)
L = 1.264 m

Total Thermal power = 48 kW

Thermal behaviour of the package submitted to fires

For each fire configuration, the temperatures of the package components have been initialized with those obtained in the Normal Conditions of Transport (NCT) as defined by the IAEA regulation (Edition 2005, TS-R-1)

Complementary hypothesis have been considered in the calculations to take into account the package damages due to the regulatory NCT tests and the internal gaps

- Heat transfers between the upper part of the spent fuel assemblies and the cavity plug
- Internal gaps :
  - primary shell / lead
  - Basket / inner shell
- Package in horizontal position during transport
- Upper plate of the basket in contact with the cavity plug

Thermal behaviour of the package submitted to fires

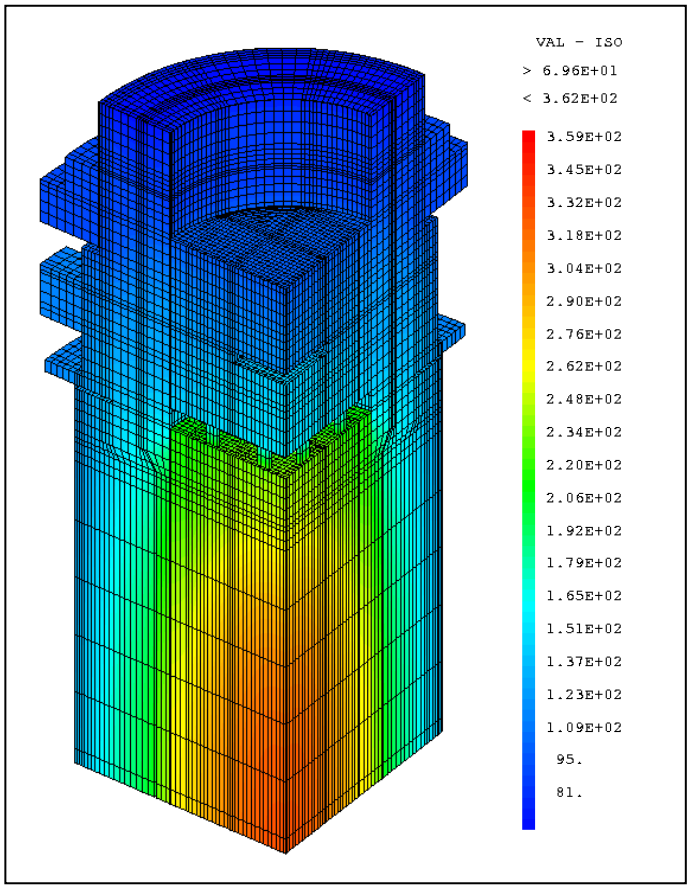
Real transport configurations under confined systems (canopies or tarpaulins) have been considered

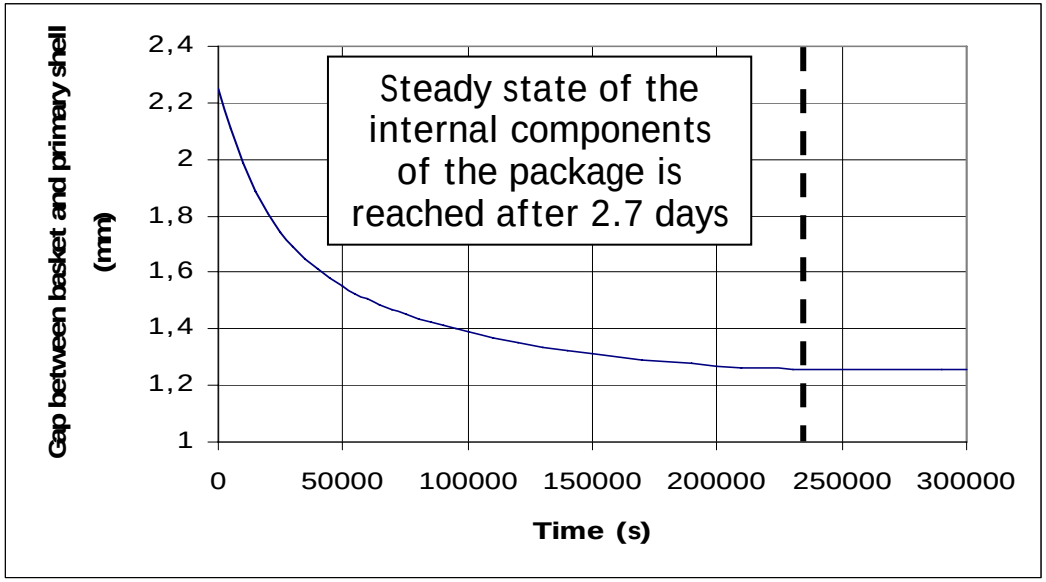
Corrected convective coefficients have been applied to the external surfaces of the package

The convective coefficients considered in the calculations have been corrected, **with a reducing factor equal to 0.7**, to obtain the same package external temperatures as those determined by the applicant

Thermal behaviour of the package submitted to fires

Temperature of the package components in NCT





Initial gap = 2.25 mm

Final gap = 1.25 mm

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Thermal behaviour of the package submitted to fires

According to IAEA regulation for transport of radioactive material, type B packages are submitted to a fire test of 800°C during 30 minutes

To complete the study presented by the applicant in the safety report, IRSN has studied the thermal behaviour of the TN®112 package exposed to several fire temperatures (range from 400 °C to 1 000 °C) and has determined the maximum durations to reach the following criteria

Maximum allowable temperature of the elastomer gaskets of the containment system

(criterion considered : 220°C)

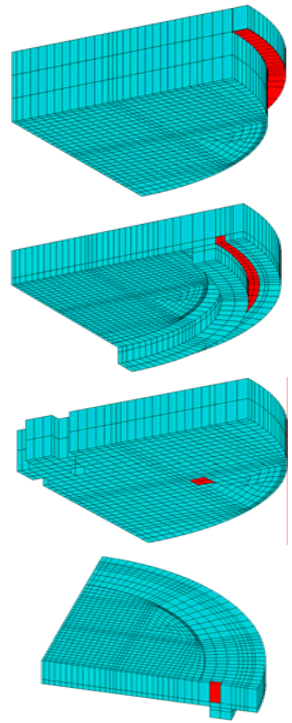
Maximum allowable temperature of the fuel rods

(criterion considered : 550°C)

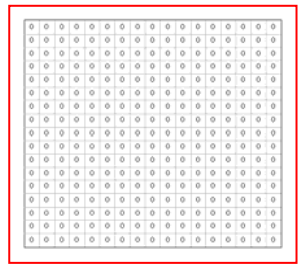
Thermal behaviour of the package submitted to fires

Maximum allowable temperature of the elastomer gaskets of the containment system

- Inner plug gasket
- Inner lid gasket
- Plug orifices gaskets
- Lid orifice gaskets



Maximum allowable temperature of the fuel rods



Additional calculations have been performed to consider the radiation heat transfers into the rods lattice

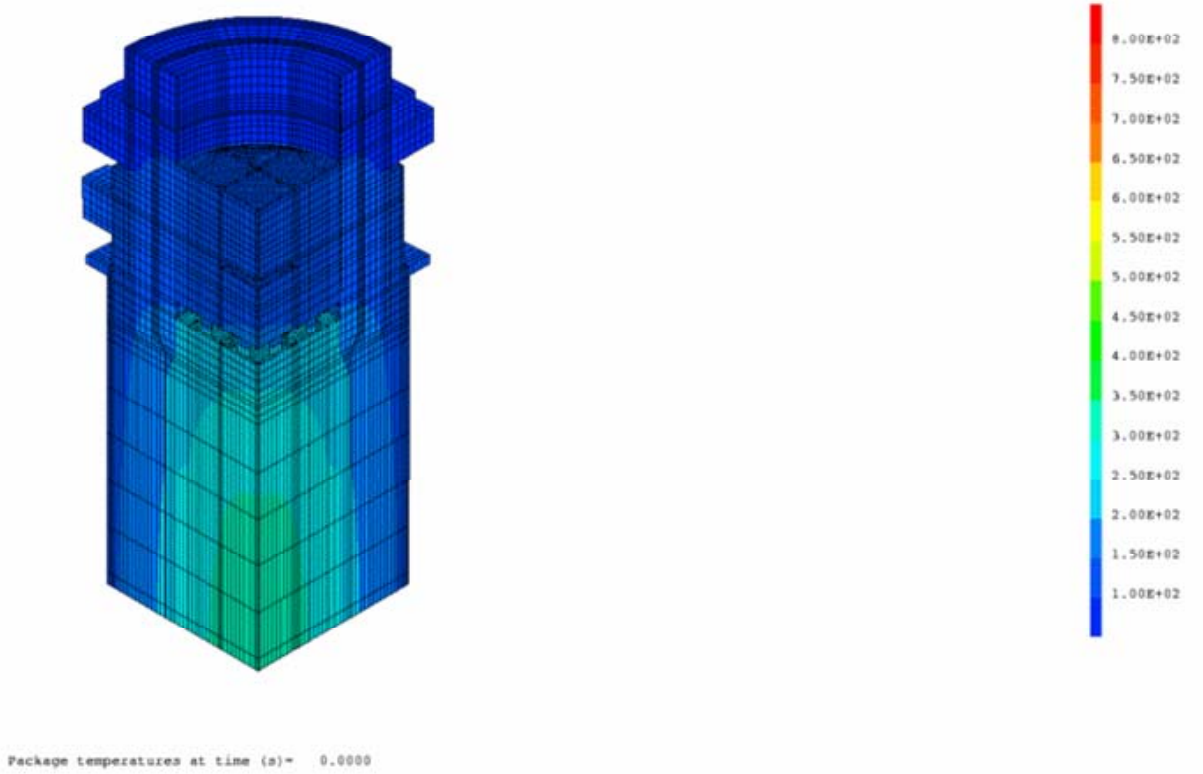
Thermal behaviour of the package submitted to fires

Main hypothesis considered in the calculations to model the package damages in Accident conditions of Transport (ACT)

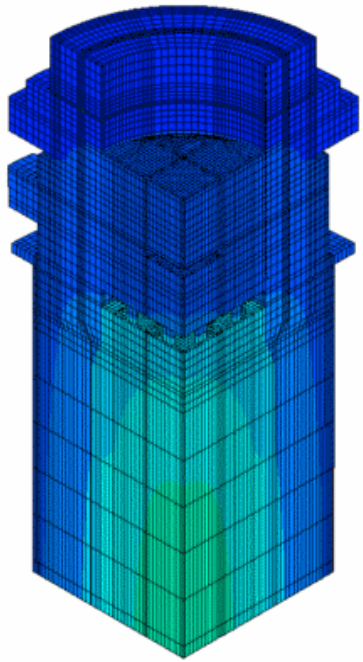
- Upper part of the spent fuel assemblies in contact with the cavity plug
- Contact between the elements of the closure system and the package body
- Convective coefficient around the package body corrected to consider the surface increase due to the copper fins presence
- Basket in contact with the cavity plug
- The thermal emissivity of the external surfaces is equal to 0.8

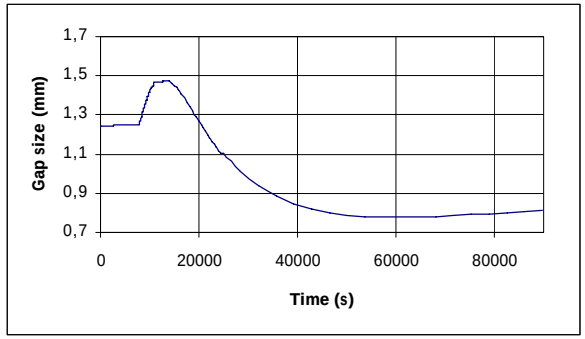
For each calculation the flame emissivity is equal to 0.9 as defined by IAEA

Thermal behaviour of the package submitted to fires



Thermal behaviour of the package submitted to fires

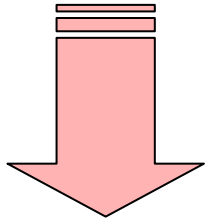




Package temperatures at time (s)= 0.0000

Data for safety assessment in emergency situations

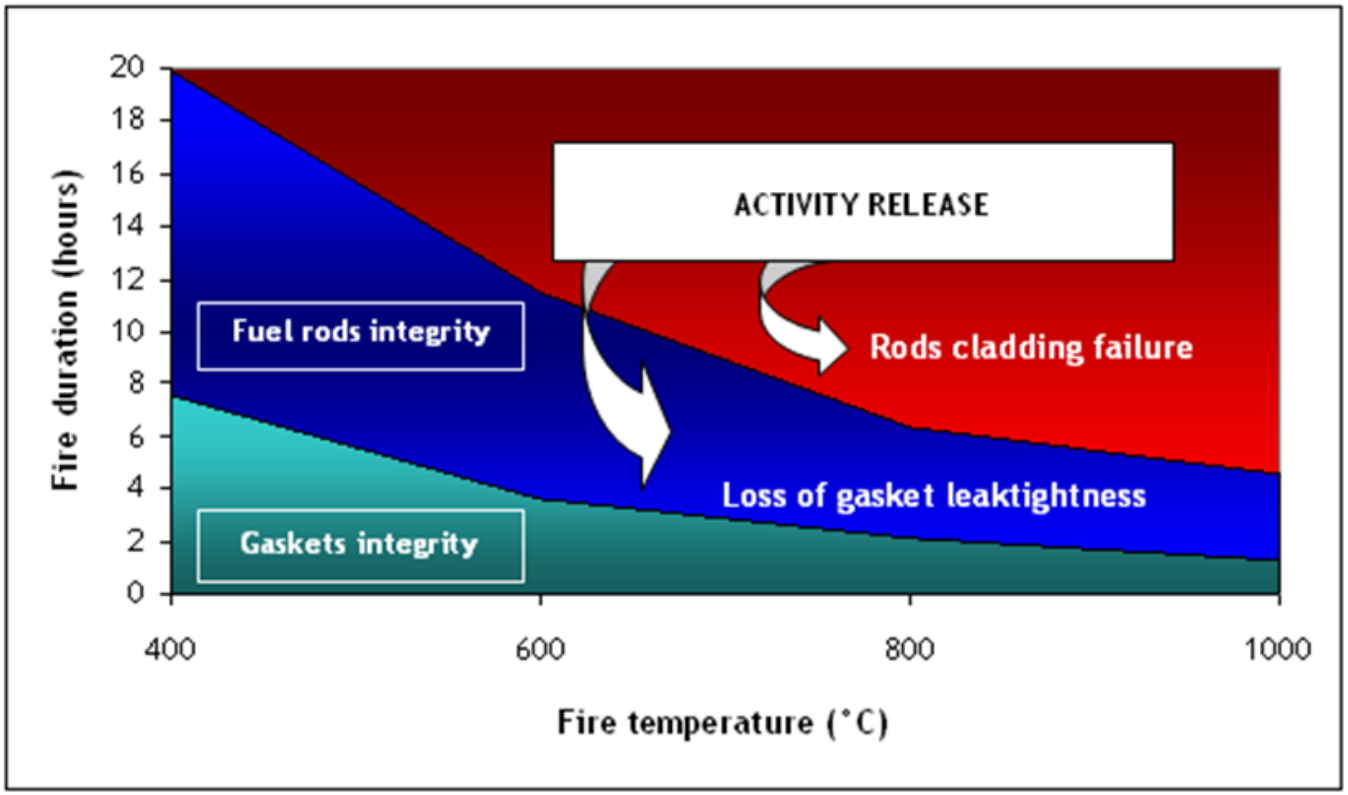
Maximum allowable fire durations



Fire temperature (°C)	Fire duration to reach gaskets criterion	Fire duration to reach fuel rods criterion
400	7 h 33 min	19 h 57 min
600	3 h 39 min	11 h 29 min
800	2 h 07 min	6 h 24 min
1000	1 h 21 min	4 h 35 min

Data for safety assessment in emergency situations

Maximum allowable fire durations



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Data for safety assessment in emergency situations

Emergency tools have been extracted from the previous results to help IRSN assessment in case of emergency situation

Equations could be used to evaluate quickly the integrity of the package components important for the safety

$$(\text{Fire Temperature } (°C))_{\text{EPDM gaskets}} = 10\,521 \times (\text{Fire Duration (minutes)})^{-0,5334}$$

$$(\text{Fire Temperature } (°C))_{\text{rods}} = 30\,323 \times (\text{Fire Duration (minutes)})^{-0,6073}$$

Conclusions

The simplified equations, issued from the results of the calculations performed, give a tool to evaluate quickly, in case of emergency situations involving fire, the consequence on the package leaktightness

However the package engulfing by the flames during the fire should also be appreciated by the emergency analysts in charge of the evaluation of the package

This study should be completed considering heterogeneous thermal loadings in the basket to cover the other possible transport configurations of the TN®112 package

Thank you for your attention

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