TRANSFER SHUTTLE FOR VITRIFIED RESIDUE CANISTERS CONTROL OF RISKS ASSOCIATED WITH EXTERNAL EXPOSURE AND HEAT RELEASE

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SUMMARY

In the La Hague COGEMA's plant area, nuclear residue isolated by reprocessing are transported by means of specific transfer shuttles between the different processing and/or conditioning facilities and the storage ones. These shuttles are designed by reference to the applicable dose equivalent rate (DER) limits for transport on the site and the thermal behavior limitations of certain mechanical components which guarantee the containment of the transported waste. This paper describes an example of a study conducted on a transfer shuttle for vitrified residue canisters. Concerning the control of risks associated with external exposure and with heat releases, these were handled by the 'Shielding-Criticality-Dispersion' and 'Process Modelling and Simulation' Sections of the Technical Division of SGN. The dose profiles around the shuttle, as a function of the shielding heterogeneities and possible radiation leakage, as well as the thermal fields within the shuttle, were calculated using 3D models.

These design studies ultimately helped to select and validate the optimal solutions.

INTRODUCTION

Irradiated nuclear fuel reprocessing isolates different types of residue in the various facilities of COGEMA's plants at La Hague. This waste must be conditioned and transported on the site to the storage facilities, and meet satisfactory safety conditions. The fission products and so-called minor actinides, such as curium, americium and neptunium, produced by the irradiation of the fuel assemblies in reactor, are confined within glass matrices in vitrification facilities of the UP3 and UP2 800 plants (T7 and R7 respectively). These vitrified residue canisters produced are intense gamma and neutron radiation sources, causing considerable heat releases.

Transport is performed using specific shuttles, designed to meet the Dose Equivalent Rate (DER) limits prevailing on the site (2 $mSv.h^{-1}$ at contact and 0.025 $mSv.h^{-1}$ at 1 m), and the thermal constraints associated with the risk of loss of containment.

Design studies to control external exposure and heat release risks were carried out in the 'Shielding-Criticality-Dispersion' and 'Process Modelling and Simulation' Sections of Technical Division of SGN. This work led to a choice of the optimal solutions validated by calculations using 3D models.

DESCRIPTION OF THE SHUTTLE CASK

The transfer shuttle is loaded with seven vitrified residue canisters placed at the bottom of the shuttle inside a massive basket with seven cavities. This shuttle consists of a cylindrical body and a hatch featuring drawers added with a safety plug. Its geometry has a number of structural details which are shown in figures 1 and 2 below.

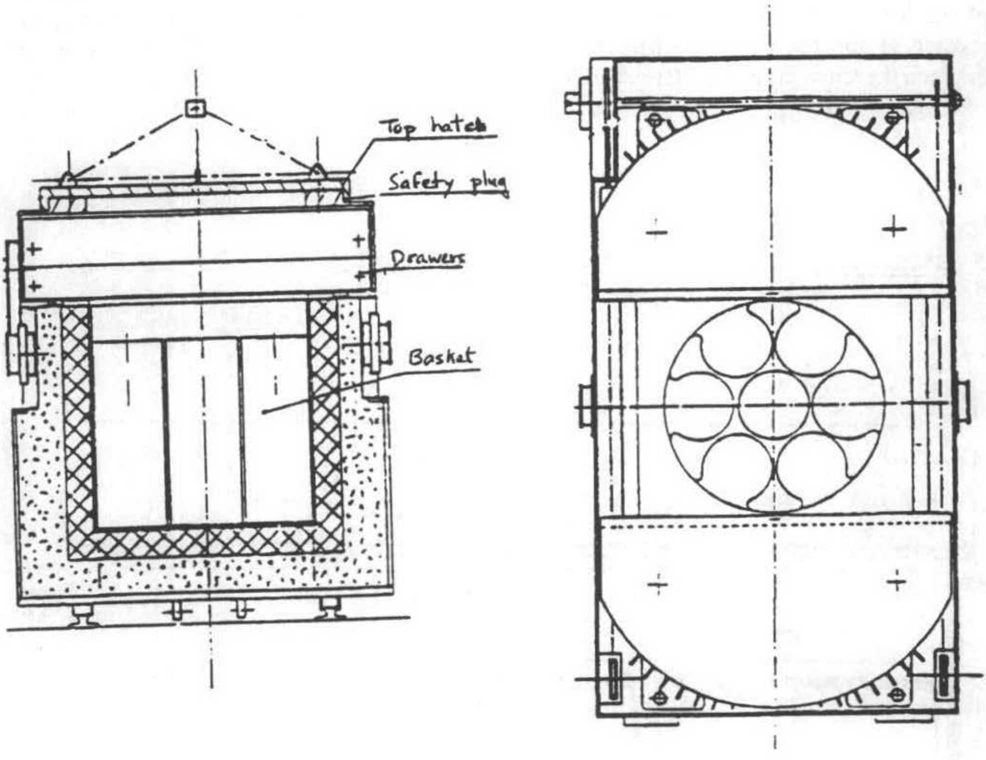


Figure 1

SHUTTLE DESIGN

To account for the thermal constraints and the applicable DER, the design of the shuttle had to be validated by several specific calculations, described below, relying on 3D models.

DER profile around the shuttle

During transport by shuttle, the vitrified residue canisters, which contain gamma and neutron emitters, require the insertion of radiation shielding designed to limit the external exposure of the facility workers. The insertion of this shielding in the body of the shuttle and the structures of its drawer hatch, although optimized to guarantee that around the shuttle the DER requirements in contact and at 1 m are maintained, demands 3D validation by calculation.

The complex geometry of the designed shuttle required the determination of the DER along the walls offering uniform shielding against the sources (stainless steel and lead thicknesses for gamma irradiation and neutron absorbent resin for neutron radiation), as well as consideration of the shielding heterogeneities (see figure below). For example, the steel lining on the drawers of the hatch induces a local shielding defect for neutron radiation. The possible radiation leakage at the functional mechanical clearance was qualified in terms of overdose (joint between the hatch drawers, interface between the drawers and the shuttle body).

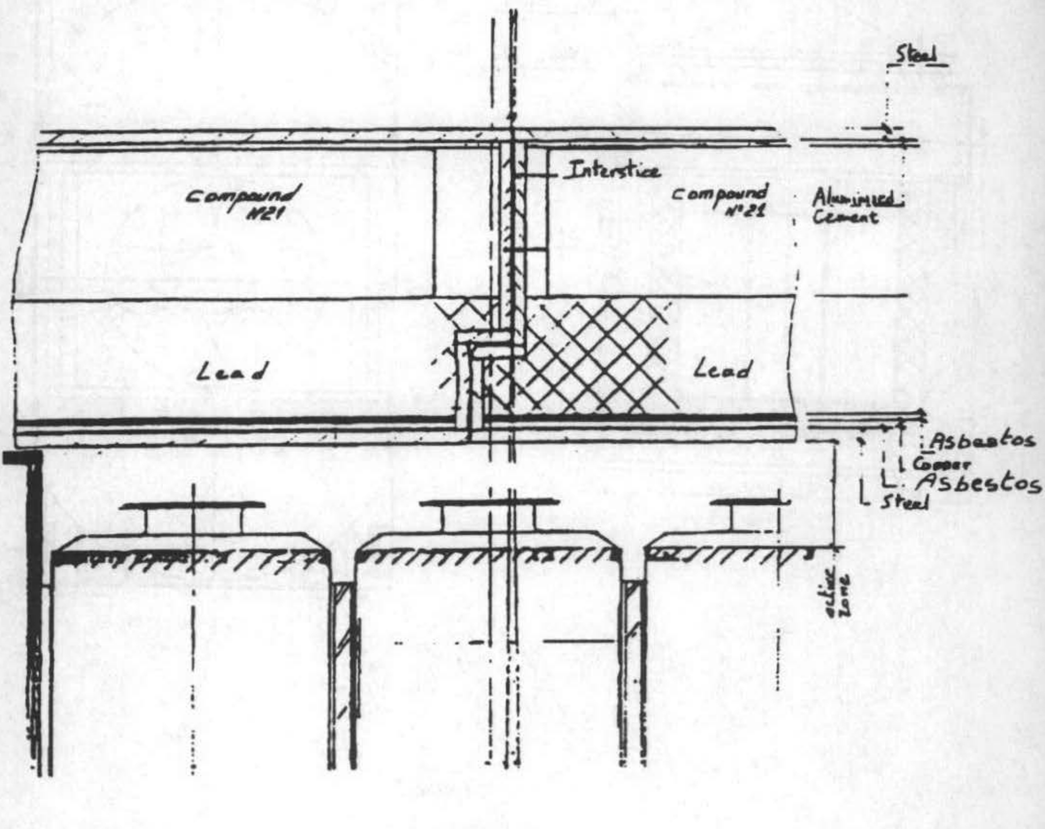


Figure 2

Problems of radiation leakage are intrinsically complicated to deal with. The leakage areas considered could also display highly irregular geometry.

The use of a Monte Carlo program, such as TRIPOLI 3.3, is indispensable for modelling such geometry. This code helps to solve the transport equation of a particle field in the phase space, and, using a biased simulation, allows one to calculate the particle flux at the points of interest.

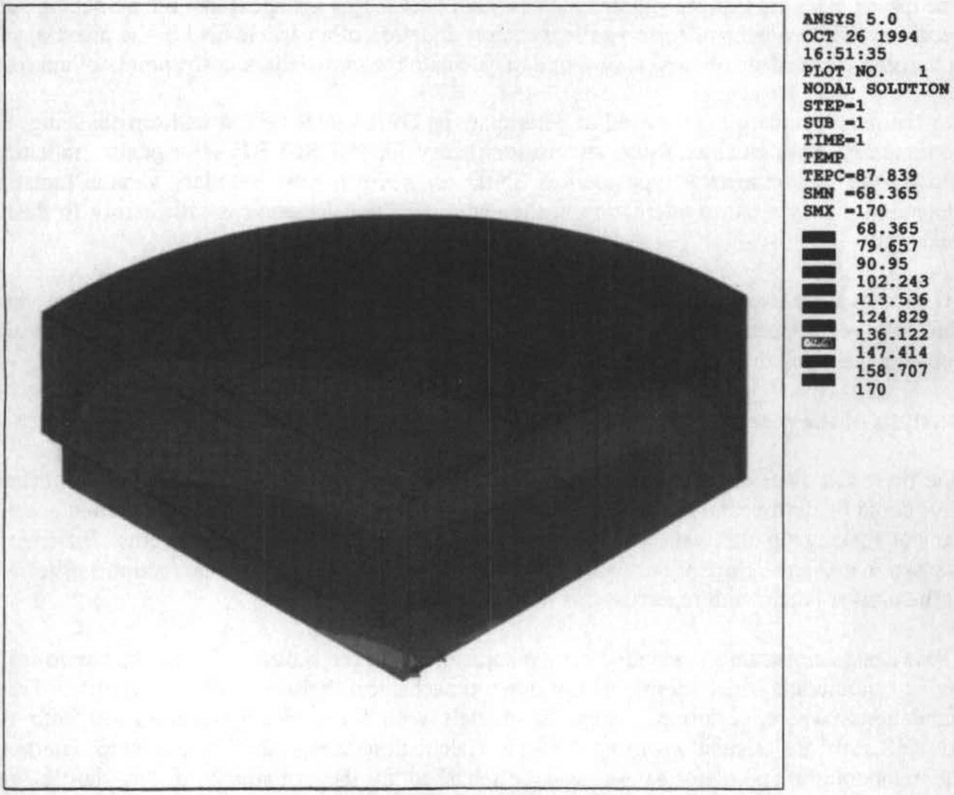
For the most standard cases aimed to determine the DER values behind uniform shielding, the codes are based upon straight-line attenuation theory, like MERCURE V for gamma radiation, and on the semi-numerical type such as SNID for neutron and secondary gamma radiation generated during neutron interaction in the material. The calculation is satisfactory to design the shuttle.

3D models were used for DER profile calculation around the shuttle.The hot spots on which shielding requirement may be needed are identified, as for instance above the interstice between the hatch drawers.

Analysis of the thermal behavior of the shuttle

The thermal power dissipated in the vitrified residue canisters can cause substantial heating. This could be detrimental to the behavior of some components, such as the compound and the cement making up the walls of the shuttle and the glass matrix in the drums. Differential expansion and any deformations caused by this heating can also lead to malfunctions, especially at the drawer hatch, with repercussions for radiological protection.

These design constraints demanded certain adjustments in the shuttle, which gave rise to tests, and to numerical simulations of the thermomechanical behavior of the shuttle. These simulations, where performed using 3D models with finite elements developed with the ANSYS software calculations using ANSYS. Calculations using ANSYS helped to determine the temperature and deformation fields established in the structures of the shuttle, and ultimately to check that the design was satisfactory.



Half shuttle drawer : temperatures

Figure 3

CONCLUSION

Although the radiation shielding thicknesses installed around the shuttle have been validated for the uniform structures of the body and the shuttle hatch, some leakage areas, although localized, must be limited in terms of the potential overdoses possible. The addition of further neutron absorbent resin shielding is therefore necessary between the top of the drawers and the safety plug to guarantee compliance with the radiological limits on transport. It is only possible to optimize the shielding solutions by using appropriate computer codes (deterministic codes for standard configurations and so-called reference Monte Carlo codes for complex cases with shielding defect or radiation leakage). The repercussions on the thermomechanical behavior of the shuttle, due to the positioning of this type of shielding, were analyzed from the results of numerical simulations carried out using 3D models with finite elements.

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