

**TN GEMINI :  
A LARGE SIZED TYPE B (U) PACKAGING FOR  $\alpha$  WASTES  
THE TEACHINGS FROM THE FIRST ROUNDS OF OPERATION**

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**ABSTRACT**

Alpha wastes are generated in fuel cycle facilities such as those involved in reprocessing, in manufacture of mixed oxide fuel, and by research laboratories. If a significant amount of wastes has to be transported, then a Type B packaging is required. The TN GEMINI container has been developed by COGEMA and TRANSNUCLEAIRE to achieve this goal.

The TN GEMINI container is a parallelepipedic packaging with a rear door allowing horizontal loading. It is similar to an ISO 20 ft container in terms of total weight, size, handling devices and tie-down capability. It provides a large internal usable volume (4.5 x 1.8 x 2 m) available for a 5.8 t payload with a 30 t total gross weight. The TN GEMINI container enables the transport of alpha wastes conditioned in drums (forty 200 liter drums or sixty 118 liter drums). The maximum licensed fissile contents have been set at 374 g of plutonium.

Dedicated internal arrangements such as pallets are used for loading, unloading and tie down of the drums. They can be loaded/unloaded with a fork lift in a manual mode or with dedicated equipment in a semi automated mode.

After two years of operation, the current challenge for the TN GEMINI container is to increase its capability in terms of the authorized residual thermal power per drum by a more realistic safety analysis of the radiolysis issue. This will allow nuclear plant operators to further optimize their waste transport management. After a general description of the TN GEMINI container and its contents, this paper briefly describes the main steps of this safety analysis (characterization of the H<sub>2</sub> production, of the H<sub>2</sub> diffusion through the waste plastic wrapper and of the H<sub>2</sub> leakage of the drum).

**INTRODUCTION**

Alpha wastes are generated in fuel cycle facilities such as those involved in reprocessing, in manufacture of mixed oxide fuel, and by research laboratories. As concerns transport, a large quantity of these wastes cannot be considered as Low Specific Activity (LSA) material, and some of them are combustible : if a significant amount of material has to be transported, then a Type B

packaging is required. The TN GEMINI container has been developed by COGEMA and TRANSNUCLEAIRE to achieve this goal.

The TN GEMINI container is a parallelepipedic packaging with a rear door allowing horizontal loading. It is similar to an ISO 20 ft container in terms of total weight, size, handling devices and tie-down capability. It provides a large internal usable volume (4.5 x 1.8 x 2 m) available for a 5.8 t payload with a 30 t total gross weight. The TN GEMINI container enables the transport of alpha wastes conditioned in drums (forty 200 liter drums or sixty 118 liter drums). The maximum licensed fissile contents have been set at 374 g of plutonium.

This container fulfills the requirements for B(U) packages according to the International Atomic Energy Agency (IAEA) regulations. In addition, it is also fully compatible with standard transport/loading equipment and does not require any stringent protection measures.

This paper (1) presents a general description of the TN GEMINI container and its contents ; (2) highlights some points related to its design and operation ; (3) illustrates how the improvement of its capability is being sought by a more realistic safety analysis of the radiolysis issue.

## GENERAL DESCRIPTION OF THE CONTAINER

The TN GEMINI container main dimensions are summarized as follows :

|                    |       |                                    |
|--------------------|-------|------------------------------------|
| Overall dimensions | ..... | 6058 x 2500 x 2650 mm <sup>3</sup> |
| Free volume        | ..... | 4510 x 1840 x 2000 mm <sup>3</sup> |
| Total gross weight | ..... | 30000 kg                           |
| Maximum payload    | ..... | 5800 kg                            |

The packaging includes three main components : the body, the containment door and the shock absorbing cover.

### **Body**

Multilayered materials make up the walls : stainless steel (for structural resistance), balsa wood and phenolic foam (for their low crushing stresses and thermal insulation capabilities). This was found the most efficient combination for the puncture resistance. The corners are protected by thick layers of redwood and balsa (for shock absorbing purposes).

### **Containment door**

Its design is similar to that of the walls. It is bolted to the body. Two concentric “O” rings made of EPDM (Ethylene Propylene Rubber) ensure the leaktightness. The very low leakage rate can be measured by means of the orifice provided at the bottom of the door. Another orifice is dedicated to gas sampling or pressurisation whenever an inert gas atmosphere is necessary within the container.

### **Shock absorbing cover**

A removable shock absorbing cover is bolted to the container body and protects the closure system during transportation. Its central part is made of two stainless steel plates and phenolic foam. Around it, materials such as stainless steel, redwood, balsa and thermal insulator are arranged in a composite structure.

The design concept of the TN GEMINI container provides a system, easy to operate. Handling by spreader beam and tie down to trailers are operated by means of the eight standard ISO anchor points located at the corners of the container (twist locks) with the geometry of standard ISO 20 ft containers.

Dedicated internal arrangements such as pallets are used for loading, unloading and tie down of the drums. They can be loaded/unloaded with a fork lift in a manual mode, or with a dedicated equipment in a semi automated mode.

## **GENERAL DESCRIPTION OF THE CONTENTS**

Typical contents are alpha wastes in drums : forty 200 liter drums or sixty 118 liter drums.

The drums are classified in two groups.

The first group of drums contains technological wastes among the following list :

- Paper/cardboard/cellulite
- Cotton
- Polymer<sup>1</sup>
- Rubbish (soil, cement, plaster)
- Iron, molybdenum and other metallic scraps
- Uranium spheres
- Zircalloy<sup>2</sup>
- Sodium phosphate

The second group of drums contains technological wastes, mainly non radiolysable and non perforating from among the following list :

- Empty Pu O<sub>2</sub> boxes
- Filter frames
- Filtering media
- Ashes (metallic oxides<sup>3</sup>)
- Oven bricks
- Silicon carbide spheres
- Glass

All these wastes have to be dry (less than 1% liquid in each drum), in solid forms, chemically stable, non-combustible, non-explosive and non-corrosive ( $2 < \text{pH} < 12.5$  in water solution). They can be conditioned in plastic wrappers.

The maximum quantity of plutonium and uranium 235 is limited by the two following inequalities :

$$\frac{m_{\text{Pu}}}{374} + \frac{m_{\text{U235}}}{620} \leq 1 \quad \text{per container}$$

$$\frac{m_{\text{Pu}}}{374} + \frac{m_{\text{U235}}}{620} \leq \frac{50}{374} \quad \text{per drum}$$

where  $m_{\text{Pu}}$  (resp.  $m_{\text{U235}}$ ) is the mass of Pu (resp. U235) in grams.

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<sup>1</sup> Vinyl sheet, vinyl polychloride, polyethylen, methylpolymetacrylate, teflon, ...

<sup>2</sup> Pieces of cladding

<sup>3</sup> ZnO, CaO, Si O<sub>2</sub>, Al<sub>2</sub> O<sub>3</sub>, Pu O<sub>2</sub>, U<sub>3</sub> O<sub>8</sub> ...

In the first certificate of approval for transport, another limitation was set to account for the assessment of the radiolysis issue. In particular, for each drum of the first group, the maximum residual thermal power was 15 mW.

## DESIGN AND OPERATION

As a B (U) packaging type, the TN GEMINI container fulfills the specific requirements of the IAEA regulations in the potential case of accident conditions during transport. The requirements include a drop resistance test (9-m drop test ; 1-m drop puncture test) and fire resistance test (a 30 minute 800° C engulfing fire). It was proven that, after the accident test conditions, the total leakage rate remained at the same level as before.

The fire test shows that the temperature of the cavity does not exceed 70° C which is quite compatible with the transport of common organic wastes.

Two units have been manufactured for COGEMA and are operated by TRANSNUCLEAIRE.

They transport alpha wastes between several facilities :

- for the French Atomic Energy Commission (CEA)
- for the Mox fuel manufacturing facilities (COGEMA)

mainly in France but also in Germany.

After two years of operation, the feedback from the operators confirmed the main advantages of the TN GEMINI container :

### **Characteristics / Advantages**

Standard ISO 20 ft / Easy handling and tie down

Great capacity / Improved safety by a reduced number of transports

Semi automatic loading system / Reduced time for loading and reduced dose rates for operators

For optimization purposes, some minor modifications of the tooling and associated operating procedure are under consideration.

However, the current challenge for the TN GEMINI container consists in increasing its capability in terms of the authorized residual thermal power per drum by a more realistic analysis of the radiolysis issue.

Measurements performed during the first transports confirmed the existence of safety margin : the variation of the fraction of  $H_2$  measured at the departure and at the arrival of the TN GEMINI container was significantly lower than the predicted variation.

We briefly describe in the next section the work which has been performed for two years about the safety analysis of the radiolysis issue. This work will increase the capabilities of the TN GEMINI container and allow nuclear plant operators to further optimize their waste transport management.

## **ANALYSIS OF THE RADIOLYSIS ISSUE**

This phenomenon consists of the chemical decomposition of materials under radiation. In our case, the effect of alpha radiation induced by plutonium on the organic materials of the wastes generates radiolysis gases.

The major issue is related to hydrogen  $H_2$ , which can be flammable or even explosive in specific conditions. In order to eliminate this, the French Safety Authorities consider that the fraction of  $H_2$  must permanently remain below the limit of 4% in each drum, even in the case of the most pessimistic transport scenario including :

- the maximum storage period,
- the maximum conceivable transport duration,
- an hypothetical accident condition, that is a regulatory fire,
- a further performance period, seven days after the hypothetical accident.

A detailed analysis and characterization of the production and diffusion of hydrogen inside the TN GEMINI container was performed. The objective was to determine the maximum mass of plutonium which can be transported in each drum.

The main steps of this analysis are :

- $H_2$  production,
- $H_2$  diffusion through the waste plastic wrapper,
- $H_2$  leakage of the drum.

### **H<sub>2</sub> production**

Typical waste conditioned in wrappers were selected, representative of :

- the waste generation within typical workshops
- the 2-year production period
- wastes with 100% organic materials
- wastes with the maximum mass of plutonium

Experiments performed on these representative waste wrappers determined the relationship between the production rate of H<sub>2</sub> (Q<sub>p</sub>) and the residual thermal power of the plutonium (P) :

$$Q_p = G P$$

where G is a constant factor, characterizing the radiolysis phenomenon, which takes into account :

- auto-absorption of the alpha radiations by the plutonium source itself,
- possible recombination, due to radiation, of hydrogen with other gases such as oxygen
- diffusion of hydrogen through the wrappers.

### **H<sub>2</sub> diffusion**

Laboratory experiments characterized the diffusion of hydrogen through the plastic material (PVC type) used as waste wrapper.

A forced circulation of gases along each side of a calibrated surface made of the plastic wrapper was performed. On one side, a controlled amount of hydrogen was mixed with the gas. On the other side, the rate of hydrogen (due to the diffusion through the calibrated surface) was measured.

As a consequence, the relationship between the diffusion rate of H<sub>2</sub> (Q<sub>d</sub>) and the difference between the fractions of hydrogen (Δ%H<sub>2</sub>) on either side of the wrapper is as follows :

$$Q_d = k \frac{S}{e} \bullet \%H_2$$

where S is the surface of the wrapper, e the thickness of the wrapper and k a constant factor depending of the materials (H<sub>2</sub> gas and plastic wrapper).

### **H<sub>2</sub> leakage through the drums**

The drums are only used as a mechanical protection of the waste wrappers which guarantee the containment of the wastes. As a consequence, no gas-leaktightness requirement is necessary for the drums.

To determine the gas-leakage rate of the drums, some of them were equipped in order to :

- inject H<sub>2</sub> gas at very low flow-rate,
- control the pressure and the temperature in the drum,
- measure the fraction of H<sub>2</sub> in the drum.

This experiment enabled to determine the relationship between the production rate of H<sub>2</sub> (Q<sub>p</sub>), the fraction of H<sub>2</sub> in the drum (%H<sub>2</sub>) and the leakage rate of the drum (Φ) :

$$Q_p = c \cdot \%H_2$$

where c is a constant factor.

### **Safety analysis**

This detailed characterization of the radiolysis parameters determined the fraction of hydrogen in each wrapper and in each drum, in a steady state mode of production, diffusion and leakage of hydrogen, with conservative data and assumptions at each step.

The expected result is that in the case of :

- a transport duration less than 30 days
- a residual thermal power less than 500 mW per drum,

the safety criteria is satisfied, corresponding to a maximum fraction of H<sub>2</sub> per drum less than 4%.

The technical expertise of this analysis by the French Competent Authority is currently in progress.

## CONCLUSION

The TN GEMINI container is a type B (U) container which provides :

- high capacity (5800 kg payload and 16.7 m<sup>3</sup> usable volume)
- total gross weight (30000 kg) complying with the French legal limit for road transport
- standard handling and tie down (as for ISO 20 ft sea container)
- easy loading and unloading procedures (horizontal with drum pallets)

Two units have been manufactured for COGEMA and are operated by TRANSNUCLEAIRE for the transport of alpha wastes in drums.

Thanks to detailed characterization of the wastes and measurements of the fraction of H<sub>2</sub>, significant improvement of the TN GEMINI container capability is expected.

This will enable the nuclear plant operators to further optimize their waste transport management.