SUMMARY

REVISION STATE

Revision	Date	Modifications	Preparation / Verification
00	01/12	Document first emission Update and translation of the French document: DOS-07-00054095-000, revision 1	G. LELEU / C. BUYCK
01	08/12	Update of the document	G. LELEU / O. DOUAUD
02	12/12	Update of the document (corrosion, specific activity demonstration)	G. LELEU / A. PARIS

1. INTRODUCTION

This report demonstrates the safety of the TN-BGC1 packaging loaded with contents n°11 under UF_4 form. These analyses are based on the safety analyses report referenced in <1> and the definition of the contents given in section 2.

The aim of this report is to extend the contents n°11 (chapter 1 of <1>, section 2.11) with uranium tetra fluoride (UF_4).

2. CONTENTS 11 CHARACTERISTICS'

Contents n°11 under UF_4 form is a powder. UF_4 is conditioned in boxes compatible with TN 90 internal arrangement dimensions.

The uranium is unirradiated and its enrichment is undefined.

The definition of the IAEA TS-R-1 regulation (reference <2>) of the unirradiated uranium is given paragraph 246, it states: *Unirradiated uranium* shall mean uranium containing not more than 2×10^3 Bq of plutonium per gram of uranium-235, not more than 9×10^6 Bq of fission products per gram of uranium-235 and not more than 5×10^{-3} g of uranium-236 per gram of uranium-235.

The other characteristics are identical with these of contents 11 which are defined in section 2.11 of the chapter 1 of <1>.

UF_4 do not have any other subsidiary risk (like pyrophoricity or hydrolysis). The use of inerted boxes and internal arrangement is not required. The chemical properties of this content are analysed in annex 1.

3. STRUCTURAL AND THERMAL EVALUATION OF TN-BGC1 PACKAGING

3.1 Structural evaluation of TN-BGC1 packaging

The main structural characteristics of the TN-BGC1 packaging loaded with the contents defined in section 2 are unchanged compare to these of the TN-BGC1 loaded with the contents n°11 defined in <1> (same maximal weight, same authorised internal arrangements).

Therefore, the structural analysis in normal and accident conditions of transport of TN-BGC1 package given in chapter 3.1 and 3.2 of <1> are still valid considering TN-BGC1 loaded with contents n°11 under UF_4 form.

The good behaviour of the TN-BGC1 loaded with the contents defined in section 2 in normal and accident conditions of transport is validated.

3.2 Thermal evaluation of TN-BGC1 packaging

As above, the main characteristics of the thermal analysis conducted chapter 3.3 of <1> for TN-BGC1 packaging loaded with contents 11 are unchanged considering the TN-BGC1 loaded with the contents defined in section 2. This contents is loaded

in the same internal arrangements and has no heat load (comprised between 0 and 340 W).

Therefore, the thermal analysis in normal and accident conditions of transport of TN-BGC1 package given in chapter 3.3 of <1> is still correct.

So the maximum temperatures of the TN-BGC1 packaging loaded with the UF_4 contents defined in section 2, in normal and accident conditions of transport, respect the regulatory criteria and the maximal using temperature of packaging and internal arrangement material.

4. CONTAINMENT

The physical forms of the contents defined section 2 and contents 11 defined in <1> are identical. The maximal specific activity is unchanged (44 A_2/g).

Therefore, containment analysis disclosed in chapter 3.4 of <1> for contents n°11 can be used for the UF_4 contents.

For UF_4 contents defined in section 2, with a maximal specific activity is limited to 44 A_2/g, a 5 lusec SLR control (in compliance with ISO 12807 standard) before shipment will ensure the compliance with the regulatory containment requirement.

Details of the calculation of the specific activity for this content are given in annex 2. The result is 4.52×10^{-4} A_2/g. The safety analysis report criterion of 44 A_2/gram is then respected.

5. SHIELDING EVALUATION

The radiation intensity of the UF_4 contents defined section 2 and the one of the contents n°11 defined in <1> are identical.

Contents n°11 is not penalising for shielding evaluation compared to other authorized contents.

Therefore, dose rates around TN-BGC1 packaging loaded with UF_4 contents defined in section 2, are less than the value given below:

- 0.2 mSv/h on package surface and 0.01 mSv/h at 2 meters of the package in routine conditions of transport
- 1 mSv/h at 1 meter of the package in accident conditions of transport.

These values comply with the regulatory criteria defined in <2>.

6. SAFETY – CRITICALITY

The safety-criticality evaluation of TN-BGC1 package is given in chapter 3.6 of <1>. In particular, contents 11 evaluation is given in appendices 3.6-1 and 3.6-8 of <1>.

This evaluation considers $U_{metallic} - H_2O$ as reference contents, which include solid uranium material under any chemical form and in particular UF_4.

Then, the safety-criticality demonstration of the TN-BGC1 packaging loaded with UF_4 contents defined in section 2, considering maximal U^{235} masses presented below (TN 90 inter diameter is 120 mm) is still valid:

Containment boundary diameter ϕ (mm)	Maximal U^{235} mass authorized for transport (kg)	N	CSI
$100 < \phi \leq 120$	7	50	1
$60 < \phi \leq 100$	15	16	3.1
$\phi \leq 60$	Any	50	1

7. CONCLUSION

The TN-BGC1 packaging loaded with UF_4 contents defined in section 2, which has sustained the cumulative effects of both mechanical and thermal tests defined for B(U) package loaded with fissile material (tests defined in the regulation <2>) ensures:

- the protection against ionising irradiation,
- the containment,
- the tightness of the packaging. Leakage of water into the containment boundary won't append during immersion regulatory test.

The safety analysis of the contents n°11 (given <1>) loaded in TN-BGC1 packaging cover up the loading of UF_4 contents as defined in section 2 in this packaging.

The package defined section as the TN-BGC1 loaded with UF_4 contents complies to the regulatory specifications of a type B(U) package loaded with fissile material listed in chapter 1 of the safety analysis report <1>.

8. REFERENCES

<1> Safety analysis report CEA reference 160 EMBAL PFM DET 08000157 A issued on 26/02/2008: « Dossier de Sûreté – TN BGC1 », detail table 1.

<2> Regulations for the Safe Transport of Radioactive Material – 2009 Edition – International Atomic Energy Agency – TS-R-1

<3> Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive matérial– 2008 Edition – International Atomic Energy Agency – TS-G-1 revision 1

<4> "Nouveau Traité de Chimie Minérale / Combinaisons de l'Uranium" Book n°XV

TABLE SUMMARY

Number	Index	Title	Page number
1	A	Chapters reference's of SAR <1>	1
		TOTAL	**1**

ANNEX SUMMARY

TABLE 1

CHAPTERS REFERENCE'S OF SAR <1>

Chapter/ Appendix	Title	Reference
0	« Introduction – sommaire » « Introduction – table of contents »	DET 08000157 A*
1	« Description des contenus » « Contents characteristics »	DET 08000158 A*
3.1	« Analyse mécanique de l'emballage TN-BGC 1 » « TN-BGC1 mechanical analysis »	DET 08000161 A*
3.2	« Analyse mécanique des contenus de l'emballage TN-BGC 1 » « TN-BGC1 contents' mechanical evaluation »	DET 08000164 A*
3.3	« Analyse thermique du modèle de colis TN-BGC 1 » « TN-BGC1 thermal analysis »	DET 08000165 A*
3.4	« Analyse du confinement du modèle de colis TN-BGC1 » « TN-BGC1 containment evaluation »	DET 08000166 A*
3.5	« Analyse de la radioprotection du modèle de colis TN-BGC1 » « TN-BGC1 package shielding evaluation »	DET 08000167 A*
3.6	« Analyse de la sûreté-criticité du modèle de colis TN-BGC1 » « TN-BGC1 safety-criticality evaluation »	DET 08000168 A*
3.6 / 3.6-1	« Emballage TN-BGC1 – Calculs complémentaires de criticité » « TN-BGC1 packaging – complementary safety-criticality evaluation »	NTT CA000481A**
3.6 / 3.6-8	« Étude de criticité de l'emballage TN-BGC 1 chargé du contenu 11 : milieu U métal à 100 % en ^{235}U » « Safety-criticality evaluation of TN-BGC1 packaging loaded with contents n°11 : metallic uranium with an enrichment in ^{235}U of 100%"»	NOT 06001680 A*

* Begin with « 160 EMBAL PFM »
** Begin with « EMB TNBGC PBC »

ANNEX 1

ANALYSIS OF THE CORROSION BY HF OF THE CONTAINEMENT BOUNDARY (1/2)

Uranium tetrafluoride can react with water and produces hydrofluoric acid. The chemical reaction is:

$$UF_4 + 2H_2O \leftrightarrow UO_2 + 4HF \qquad \textit{reaction (1)}$$

This reaction doesn't occur at temperature below 100°C (reference <4>). Then there is no production of HF in routine and normal conditions of transport, during which the temperature in the cavity of the package, calculated in chapter 3.3 of the safety analysis report, remains below 100°C.

In accident conditions of transport, the temperature in the cavity reaches 144°C. At this temperature, reference <4> states that 1.4% of the vapour is transformed in hydrofluoric acid.

UF_4 powder is dry but it remains 0.5% in weight of moisture. So considering a maximal mass transported of 10 kg of HEU uranium tetrafluoride this gives 50 g of water.

50 grams of water equal to 2.8 moles of water (see data table below).

2.8 moles of water will be transformed by the reaction (1) at 144°C in 3.9×10^{-2} mole of HF gas.

Then, considering the reaction below, the loss of metal due to the reaction of this HF with the containment boundary can be evaluated.

$$Fe + 2HF \leftrightarrow FeF_2 + H_2 \qquad \textit{reaction (2)}$$

This gives 1.94×10^{-2} mole of iron consumed, or 0.5 gram. And considering the density of iron this quantity equals to 65 mm^3.

The global surface of the cavity is:

$$S_{Cavity} = \pi/4 \times D^2 + \pi \times D \times L = \pi/4 \times 178^2 + \pi \times 178 \times 1475 = 8.2 \times 10^5\, mm^2$$

Then considering a global corrosion on this surface, the thickness of metal lost would be:

$$T = V_{Iron}/S_{Cavity} = 65/8.2 \times 10^5 = 8 \times 10^{-5}\, mm \text{ of iron.}$$

So the tightness of the containment boundary is not impacted by the chemical reaction of the content.

ANNEX 1

ANALYSIS OF THE CORROSION BY HF OF THE CONTAINEMENT BOUNDARY (2/2)

DATA TABLE:

Data	Unit	Value
Molar mass Water	gram / mole	18
Molar mass HF	gram / mole	20
Molar mass Iron	gram / mole	26
Volume mass of Iron	gram / cm^3	7.87
diameter of the cavity	mm	178
Length of the cavity	mm	1475
Thickness of the cavity	mm	6

ANNEX 2

CALCULATION OF THE MAXIMAL SPECIFIC ACTIVITY FOR CONTENT NUMBER 11 (1/2)

Considering the definition of unirradiated uranium given paragraph 2 and the maximum mass of ^{235}U authorised for air transport in the certificate of approval (7000 grams), the activity in A_2 and the specific activity (A_2 / gram) of the content can be calculated.

1/ Activity of plutonium:

Calculation of the maximum activity in Becquerel:

$$A_{plutonium} = M_{^{235}U} \times 2 \times 10^3 = 7000 \times 2 \times 10^3 = 1.4 \times 10^7\, Bq$$

The most conservative A_2 value for plutonium radioisotopes is these of ^{239}Pu: 10^9 Bq

Then the activity of the plutonium in A2 is:_ $A'_{plutonium} = \dfrac{1.4 \times 10^7}{10^9} = 1.4 \times 10^{-2}\, A_2$

2/ Activity of fission products:

Calculation of the maximum activity in Becquerel:

$$A_{fission\_products} = M_{^{235}U} \times 9 \times 10^6 = 7000 \times 9 \times 10^6 = 6.3 \times 10^{10}\, Bq$$

The most conservative A_2 value for fission product is this of the unknown beta-gamma radionuclides value given table 3 of the TS-R-1: 2×10^{10} Bq.

Then the activity of the fission products in A_2 is: $A'_{fission\_products} = \dfrac{6.3 \times 10^{10}}{2 \times 10^{10}} = 3.15 A_2$

3/ Activity of ^{236}U:

Calculation of the maximum mass of ^{236}U in gram:

$$M_{^{236}U} = M_{^{235}U} \times 5 \times 10^{-3} = 7000 \times 5 \times 10^{-3} = 35 g$$

The specific activity of ^{236}U given in the table II.1 of the AIEA TS-G-1 is 2.4×10^6 Bq/g.

$$A_{^{236}U} = M_{^{236}U} \times 2.4 \times 10^6 = 35 \times 2.4 \times 10^6 = 8.4 \times 10^7\, Bq$$

The most conservative A_2 value for ^{236}U is: 6×10^9 Bq.

Then the activity of the ^{236}U in A_2 is: $A'_{^{236}U} = \dfrac{8.4 \times 10^7}{6 \times 10^9} \times = 1.4 \times 10^{-2}\, A_2$

ANNEX 2

CALCULATION OF THE MAXIMAL SPECIFIC ACTIVITY FOR CONTENT NUMBER 11 (2/2)

Conclusion: the conservative activity of the content is:

$$A'_{plutonium} + A'_{fission\_products} + A'_{^{236}U} = 1.4\times10^{-2} + 1.4\times10^{-2} + 3.15 = 3.18 A_2$$

And the specific activity of the content is:

$$Specific\_Activity = \frac{3.18}{7000+35} = 4.52\times10^{-4}\, A_2 / gram$$