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THE EB3-A400/300 OVERPACK – A PACKAGING FOR THE TRANSPORT OF FISSILE MATERIAL STORED IN DOT 7A DRUMS

Alexia Favre
Nuclear Cargo + Service GmbH
(DAHER-NCS)

Wolfgang Bergmann
Nuclear Cargo + Service GmbH
(DAHER-NCS)

ABSTRACT

In the early 90´s enriched uranium ashes were transported from the USA to France in 860 inner drums DOT 7A and outer drums of type DOT 17H. Since then, these drums are stored in France. The DOT certificate for the DOT 17H drum expired and was not prolonged. Therefore a transport under this certificate is no longer possible.

To enable the transport of this material without extensive repacking, DAHER-NCS developed a packaging which allows the transport of the filled DOT 7A drum. This packaging is designed as a set of drums. The package is compounded of: the outer EB3-A400/300 drum, the rock wool layer, the inner EB1-A200 drum and finally the DOT 7A. Such a design allows the separation of the safety functions. The outer EB3-A400/300 drum has a mechanical protection function, the rock wool has a thermal protection function and the inner EB1-A200 drum has containment and confinement functions.

The application for the package approval has been submitted to the competent French Authority to be licensed in France for LSA II fissile material as an IP-2 packaging, for transport by road, rail and sea.

For the safety proof, DAHER-NCS has performed tests for normal, routine and accidental conditions of transport. The EB3-A400/300 packaging has undergone drop tests (from 1.3 m, drop test on a bar, crush test from 9m), water immersion test, criticality and thermal calculations (simulation of a fire accident at 800°C for half an hour). After the drop tests, the EB1-A200 drum has shown no significant damages and no leakage above the criterion of 1E-4 Pa m^3 s^{-1}. Thermal calculations have shown that the rock wool has ensured its thermal protection role, the temperature inside the DOT 7A drum remains well below 100 °C.

All these successful tests have proven the safety of the EB3-A400/300 package and the license can be adapted to other materials stored in DOT 7A drums.

1. INTRODUCTION

At the present time 860 inner drums DOT 7A and outer drums of type DOT 17H containing incineration products with non-irradiated enriched uranium oxide, up to 3.6 wt% in ^{235}U, are stored in France. The DOT certificate for the DOT 17H drum expired and was not prolonged. Therefore a transport under this certificate is no longer possible.

To enable the transport of this material without extensive repacking, DAHER-NCS has developed a packaging which allows the transport of the filled DOT 7A drum.

The package design EB3-A400/300 is presented to be licensed in France as a package of Type IP-2 for fissile radioactive material for transport by road, rail and sea.

The following presentation contains a description of the overpack design and a summary of the performed tests under normal conditions of transport and accidental conditions of transport: drop tests, thermal test, and criticality calculations.

2. DESCRIPTION OF THE EB3-A400/300 OVERPACK

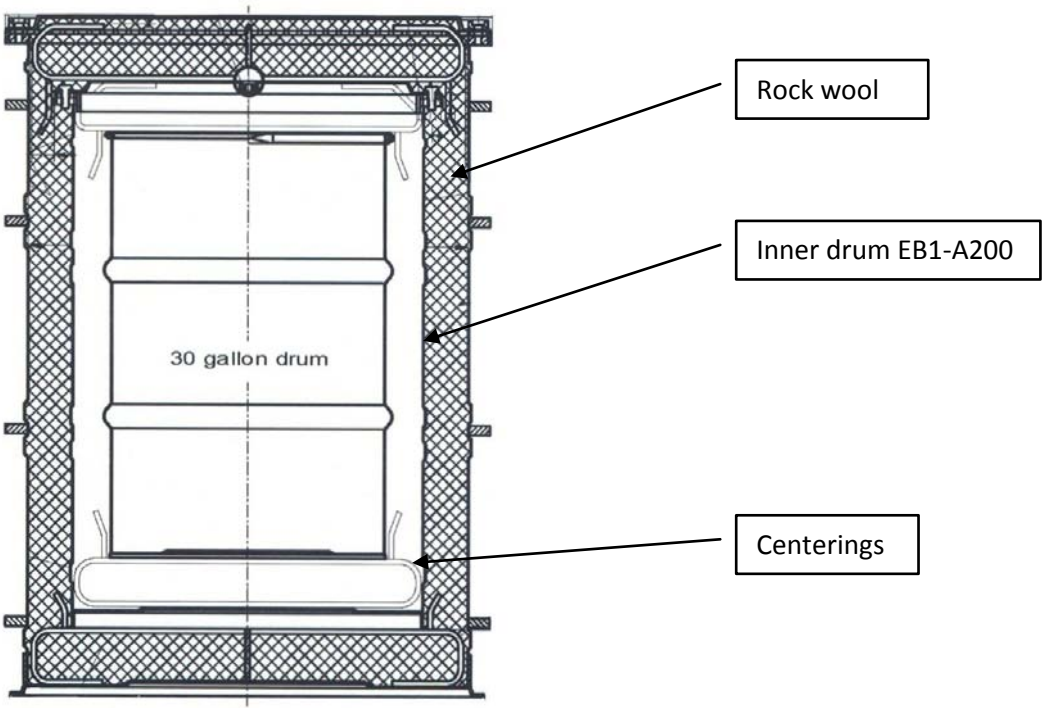
The packaging system consists of three different types of drums put inside one another:

- The outer EB3-A400/300 drum (mechanical protection)
- The inner EB1-A200 drum (containment and confinement functions)
- The 30 gallon DOT 7A drum

Picture 1. EB3-A400/300 (left side), EB1-A200 (middle), DOT 7A (right side) and centrings (front)

The empty space between the outer EB3-A400/300 drum and the inner EB1-A200 drum is filled with rock wool for thermal insulation. Between the EB1-A200 drum and the inner 30 gallon DOT 7A drum spacers are used for centering.

The maximum gross weight is 300 kg.



Picture 2. EB3-A400/300 package

2.1. The EB3-A400/300 drum

The EB3-A400/300 drum is a 400 liter drum with screwed on lid. It consists essentially of material carbon steel (according to EN 10111 and EN 10025).
The drum consists of a body shell with 2 mm thickness welded to a bottom plate with 4 mm thickness and a lid with 4 mm thickness. The lid is fastened to the lid flange of the body by 20 hexagonal screws. The inside of the body shell is reinforced at the upper end by a 3 mm thick reinforcement plate and at the lower end by a 5 mm thick ring and at the outside of the body shell 4 mantle rings are welded to improve the stiffness of the body shell. The lid is sealed against the body flange by a SBR (Styrol-Butadiene-Rubber) gasket 55° Shore.

The main nominal dimensions are:

- outer diameter: 788 mm
- inner diameter: 710 mm
- height: 1099 mm

2.2. The EB1-A200 drum

The EB1-A200 drum is a 200 liter drum with screwed on lid. It consists essentially of material carbon steel (according to EN 10111 and EN 10025).
The drum consists of a body shell with 2 mm thickness welded to a bottom plate with 4 mm thickness and a lid with 3 mm thickness. The lid is fastened to the lid flange of the body by 20 hexagon screws.
The lid is sealed against the body flange by a special profile gasket 80° shore. The lid is equipped at the centre with a test adapter made of stainless steel the opening of which is closed by a hexagon socket screw and a graphite gasket. This connection is used for the leak tightness test of the drum EB1-A200 before transport.
The main nominal dimensions are:

- outer diameter: 626 mm
- inner diameter: 560 mm
- height: 884 mm

2.3. The DOT 7A drum

The inner DOT 7A drum in which the radioactive material is stored is a 30 gallon (~110 l) drum which meets the requirements for packing group I of the UN dangerous goods regulations as required in the US Code of Federal Regulations.
The body and bottom consist of low carbon steel sheet with a nominal thickness of 1.2 mm and a removable lid of also nominal 1.2 mm thickness. The body seams are welded. The closure of the lid is provided by a clamping ring of nominal thickness 2.7 mm with drop forged lugs, one of which is threaded and having 5/8 inch (~ M 16) bolt and nut. To prevent leakage the closure system is provided with a gasket.

3. CONTENT

The radioactive material consists of incineration products, ashes, containing non-irradiated uranium in the form of U_3O_8. Some non-burnable metallic residues are also present in the drums.

The maximum mass of uranium per drum is 13.7 kg and the maximum mass ^{235}U is 0.35 kg. The maximum enrichment ^{235}U is 3.6 wt%.
These ashes satisfy the requirements for LSA-II material, because the A_2 value for uranium enriched to 20% or less is unlimited.

4. SAFETY ANALYSIS

4.1. Mechanical

4.1.1. Drop Test Program

To perform the drop tests, six specimens of the EB3-A400/300 and EB1-A200 were used. The 30 gallon DOT 7A drums were filled with glass bead up to the required gross mass (minimum 81 kg). On the upper side, screws and nails were placed to simulate the sharp parts in the material.

Picture 3. Fictive content

The drop sequences, see table 1, were performed according /1/.

Sequence n°	Orientation	Drop test
Sequence 1	Bottom edge	Drop from 1.3 m height [1]
		9 m crush test
		1.07 m drop onto a bar [2]
Sequence 2	Lid edge	Drop from 1.3 m height [1]
		1.07 m drop onto a bar [2]
		9 m crush test
Sequence 3	Mantle line	Drop from 1.3 m [1]
		9 m crush test
		1.07 m oblique drop with an angle of 25° onto the bar [2]
Sequence 4	Lid	Drop from 1.3 m [1]
		9 m crush test
		1.07 m drop onto a bar with an angle of 25° [2]
Sequence 5	Bottom	Drop from 1.3 m height [1]
		9 m crush test
		1.07 m drop onto a bar with an angle of 25° [2]
Sequence 6	Mantle line	Drop from 1.3 m height [1]
		9 m crush test
		1.07 m drop onto the bar at the lower side of the lid flange with an angle of 25° [2]

Table 1. Drop Test sequences

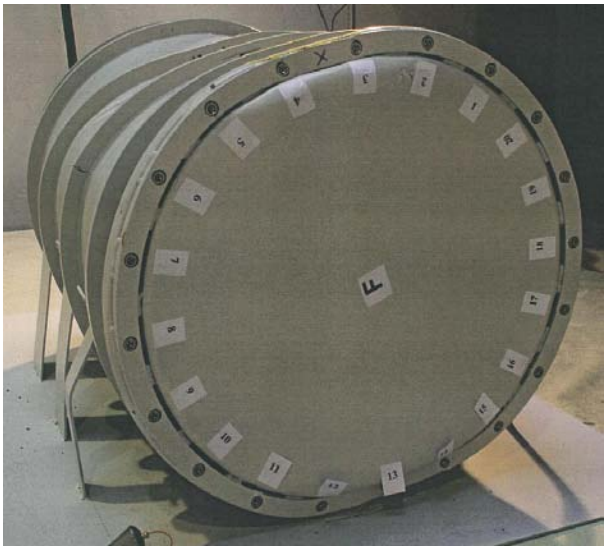
[1] [2] The mass of the complete test specimen was 280 kg. Since the design gross mass is 300 kg the drop height for the 1.2 m drop test was raised to 1.3 m and the height of the 1 m bar drop test to 1.07 m.

After the drop tests, the outer EB3-A400/300 drum was severely damaged, but the lid was still fastened closely to the lid flange. The inner EB1-A200 drum, which constitutes the containment and confinement, was only during two test sequences slightly dented, but it kept its overall geometry.

Picture 4. Mayor deformations of the outer EB3-A400/300 drum after 9 m crush test

Picture 5. Mayor height reduction

The maximum reduction in height occurred after the 9 m crush test onto the lid side (remaining total height: 100 cm)



Picture 6. Mayor diameter reduction

The maximum diameter reduction of the outer EB3-A400/300 drum occurred after the horizontal 9 m crush (remaining total diameter: 680 mm)

4.1.2. Puncture tests

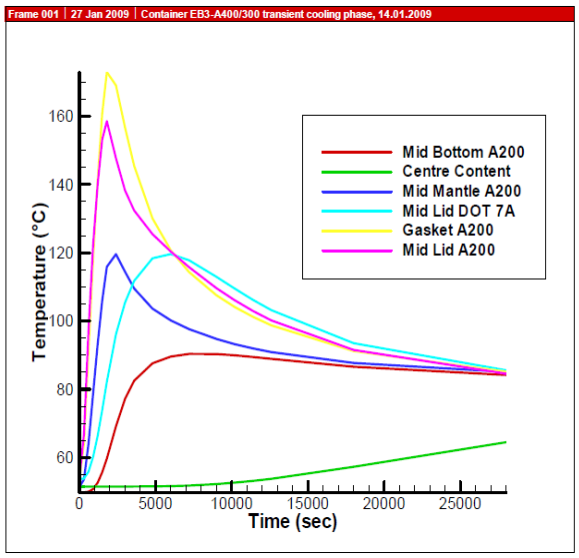
To consider the impact of a metallic object present in the content onto the containment function, puncture tests will be performed.

These tests will consist of a drop of a sharp projectile onto the DOT 7A. They will demonstrate that in accidental conditions of transport, the metallic objects present in the content cannot influence the containment function of the EB1-A200 drum.

4.2. Thermal

The steady-state and transient temperature distribution under routine and normal transport conditions and in case of an accident fire is calculated with the program HEATING 7.2. The simulation consists of an 800°C fire during 30 minutes.

The results of all transient calculations independent from the used model show that the temperatures of the outer EB3-A400/300 drum reach in a few minutes the value of approx. 800 °C after the fire starts and also decrease very quickly within minutes after the end of the fire.
The temperature of the rock wool reaches at the outside the maximum of approx. 800 °C. Due to the very low thermal rock wool's conductivity the temperature decreases very quickly in the rock wool layer.
In areas of deformation (lid, mantle) the maximum temperatures of the EB1-A200 drum are reached shortly after the end of the fire and are also decreasing very quickly. The temperature inside the DOT 7A drum remains well below 100 °C.



Picture 7. Distribution of the damaged package with reduced height and diameter under accident conditions for t = 1800 sec (end of fire)

Because after the drop tests the rock wool is compacted, DAHER-NCS is characterizing and evaluating the impact of this compaction on the thermal behavior of the overpack at very high temperature. The data resluting from this study will optimize the previous thermal model.

4.3. Criticality

The criticality analysis calculations were performed with the program SCALE 5.1 by using the control module CSAS6 in connection with KENOVI by using the cross section library 44GROUPNDF 5 and the functional module CENTRM as standard. In general, the default value 203 neutrons generation was used.

The confinement system of the radioactive content is built under normal transport conditions and under accidental conditions by the inner EB1-A200 drum with lid, gasket and screwing.

- Package in isolation undamaged or damaged according to the tests for accident conditions. Fully flooded and fully reflected at the outside

- 5 times the number of packages after the tests for routine and normal conditions of transport with an at least 20 cm water reflector around the array
- 2 times the number of damaged packages after the tests for accident conditions of transport with an at least 20 cm outer water reflector around the array and optimum moderation between the packages

To evaluate the most unfavorable criticality condition it is assumed as well that the fissile material remains inside the inner DOT 7A drum as that the fissile material escapes from the inner drum and is distributed inside the EB1-A200 drum.

The results show for the single package in insulation and for normal and accidental conditions of transport the value of $k_{eff} + 2\sigma$ are below the allowable value of $k_{eff} + 2\sigma = 0{,}95$ for an allowable number of N=252.
In all cases (single package, 5N packages and 2N packages) conservatively it is assumed that water of optimum moderation is inside the containment and confinement system.

4.4. Containment and confinement

The containment and confinement functions are ensured by the EB1-A200 drum in normal, routine and accidental condition of transport. A silicone gasket ensures the confinement of the radioactive material inside the drum.
After completion of the six drop test sequences a soap bubble test had been performed onto the inner EB1-A200 drum. The soap bubble test had shown no leakage (criterion 1E-4 Pa m^3 s^{-1}).

The thermal simulation shows that the maximal temperature in the gasket area is less than the operating limit of the gasket. Hence the confinement function is not damaged because of the fire accident.

The mechanical tests for accidental conditions and the thermal analysis demonstrated that the inner EB1-A200 drum remains leak tight when performing a bubble test. Therefore no solid material can escape from the system.

4.5. Shielding

Considering the low radiation level of the content, no particular shielding calculations have been performed.

5. CONCLUSIONS

The EB3-A400/300 overpack design fulfills all the requirements toward an IP-2 package design for the transport of fissile material up to an enrichment of 3.6 wt%. The license for this overpack is expected for the end of this year.
This license could be adapted to other materials stored in DOT 7A drums or similar drums.

6. REFERENCES

/1/. Regulations for the Safe Transport of Radioactive Material, 2009 Edition International Atomic Energy Agency (IAEA), No. TS-R-1