Helicopter drop testing of Type B packages in the UK

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ABSTRACT

Testing was carried out in the UK in 1986 to demonstrate the ability of two Type B packages designed to pass the 9m drop test criteria in the IAEA SS6 1985 transport regulations, to provide a high degree of containment even under an extended drop test as might result from a package being released from an aircraft in a mid air incident at high altitude. The tests showed that the contents would be completely contained within the containment vessel of the package.

This paper is presented to document these tests, on packages used for the transport of radioactive materials, which have not been reported elsewhere. This data serves as a useful addition to the literature of extra regulatory testing that has been carried out on an International basis

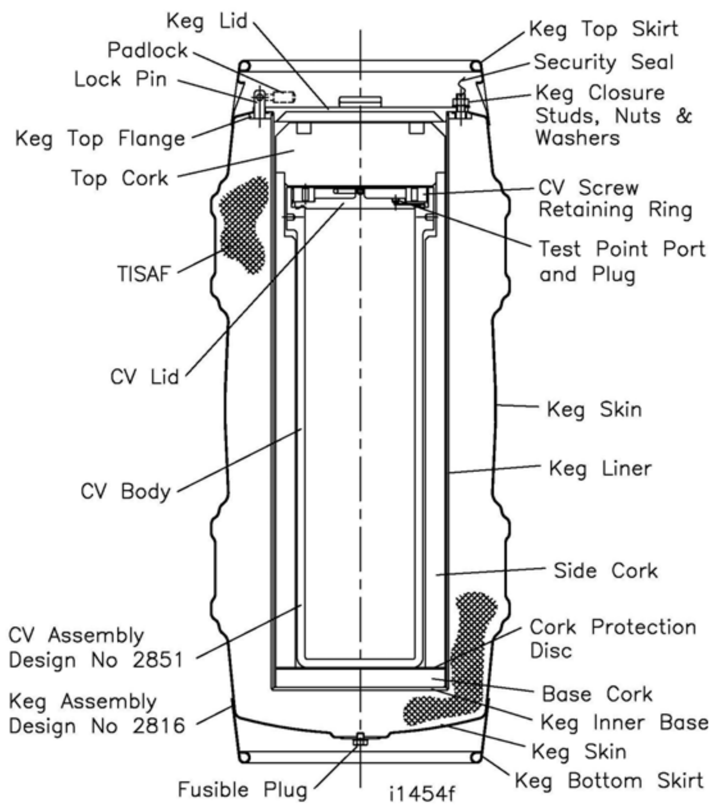
INTRODUCTION

As is commented in other papers presented in this conference, the adequacy of the package test standards specified in the International Atomic Energy Agency (IAEA) Regulations for the Transport of Radioactive Materials has been questioned from the first issue of these regulations [1] in 1964. In the 1970s concern was raised in the USA of the adequacy of Type B packages carrying Plutonium when shipped by air. This resulted in special provisions being issued in 1978 by the US NRC for such packages in NUREG-0360 [3]; this was followed in 1987 by even more onerous requirements in the Murkowski Amendment [2]. The same concern was also raised in the UK in both the nuclear industry and parliamentary committee discussions. As a result of these concerns BNFL instigated a testing program to demonstrate the ability of Type B packages designed to pass the 9m drop test criteria in the IAEA SS6 1985 transport regulations [4], to provide a high degree of containment even under an extended drop test. The extended drop test was designed to have impact velocities close to the terminal velocity that a package would reach if it were released from an aircraft in a mid air incident at high altitude. In December 1986 two different SAFKEG 2816 packages (Design Numbers 2816A and 2816C), having different inner containment vessels and contents, were drop tested from a helicopter onto an essentially unyielding concrete target. This paper reports primarily on the 2816C package as this package has been fully tested to the IAEA regulatory tests; comments are also made on the results of testing the 2816A package. The testing was carried out by AERE Harwell, UKAEA on behalf of Croft Associates Ltd (the package designer and design authority) and BNFL who were proposing to use the package.

SAFKEG 2816C PACKAGE DETAILS

SAFKEG 2816C Package Design

The 2816C package design is one of the Croft SAFKEG series of packages which all have an outer container (keg) based upon a stainless steel keg (similar to those used in beer kegs). This outer container is provided with a stainless steel liner, the interspace being filled with TISAF (Thermal Insulating and Shock Absorbing Foam - a phenolic resin blown foam of density 0.45 g/cc). The outer keg carries a single resealable leak-testable stainless steel containment vessel within cork packing. The 2816C package is a general purpose container for the shipment of fissile and non-fissile material in solid (including powder) form. The 2816C packaging consists of a Keg Assembly Design No 2816, carrying a single Containment Vessel (CV) Assembly Design No 2851 within an insulating cork liner. The assembled packaging has an overall length of 1,000 mm and an overall diameter of 425 mm. Calculations and an immersion test have shown that the packaging (without contents) has a density of greater than one. The tare mass of the packaging is nominally 115 kg (excluding contents). The maximum contents mass is 25 kg giving a nominal gross package mass of 140 kg. The major components of the 2816C packaging are shown in Figure 1 and the assembly of the contents of the containment vessel used in the drop tests is shown in Figure 2.



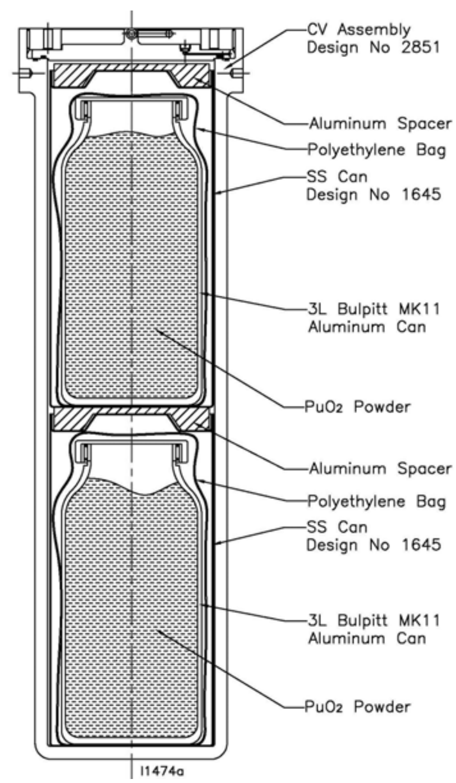


Figure 1 - SAFKEG Design No 2816C showing the components as assembled for shipment

Figure 2 - Assembly of the Contents in the Containment Vessel

Component	Colloquial Name	Design N° / Serial N°	Overall Dim (mm)	Weight (kg)	Unit/ Package
Outer	Keg	2816/003	Ø 425x1,000	67	One
Inner	Containment Vessel	2851/001	Ø 157x645	43	One
Cork (top, side and base)	Cork Packing-	-	-	5	One
Packaging Assembly	SAFKEG	2816C	Ø 425x1,000	115	One
Contents	SS Storage Can	1645 Design Code 31	Ø 153x311 (6"x12¼")	1.5	Two
	3L Bulpitt Mk II Al Can (filled with lead shot and sand)	Design Code 22	Ø 131x285 (5.15"x11.2")	9	Two
	Al spacers			Negligible	
Total contents				21	One assy
Package		2816C		136	

The basis of the design of the 2816C packaging is that the outer keg is designed to sacrificially protect the inner containment vessel by deformation of the keg and ablation of the TISAF within the keg. Furthermore, the containment vessel remains completely protected and undamaged (with containment being within regulatory limits) by the keg and cork packing, under both Normal and Accident Conditions of Transport.

Test Package

The SAFKEG 2816C package used in the drop test consisted of the following components (see Figure 3) - this was a standard package unmodified for the tests, excepting only addition of the external painting to facilitate high speed cine and video recording of the package in flight.

The inner 3L Bulpitt Mk II Al Can was completely filled with lead shot and sand with the mix adjusted to achieve a total weight of 9kg and the screw lid tightened down. The can was bagged (in lay-flat polythene 0.0035" thick) before being inserted in the SS Storage Can which was helium filled and the lid welded in place.

Following welding, the SS Storage Can was leak tested at AERE, Harwell in a helium mass spectrometer and found to be leaktight with a leakage rate sensitivity of $< 1 \times 10^{-10}$ bar cc/s.

Test Target

The target for the drop test was the concrete target area at the Porton Experimental Ground, Porton Down. The target was shown to be essentially unyielding as the concrete surface merely scuffed at the point of impact and there was no cracking of the concrete, indicating minimal energy absorption by the concrete.

Figure 3 - Package 2816C components before assembly for testing

Figure 4 - Package 2816C slung from Helicopter before the Drop Test

TEST RESULTS

Test Drop Data

The drop test had been intended to be from nominally 600 m (2,000 ft) which would have ensured that the package reached terminal velocity of 81 m/s (265 ft/s) at impact, but low cloud and poor visibility forced the drop to be from 500 m (1,650 ft). The package was dropped with axis horizontal (see Figure 4) but tilted in flight (it did not spin) such that at impact it was in an attitude of 40^{o} from horizontal with the closure end (lid end) lower than the closed end. The impact occurred about 18 m (60 ft) from the edge of the concrete target (where the concrete was seen to have not yielded) and the package bounced several times before coming to rest, with the rebound after first impact being about 6 m (20 ft).

The test data for the drop of the SAFKEG 2816C package is given below.

Parameter	Value	Comments
Drop height	500 m (1650 ft)	
Impact velocity	75 m/s (245 ft/s, 167 mph)	About 90% of terminal velocity
Deformation of the package at impact point	~100 mm	
Estimated average impact deceleration	2,700 g	Assessed from stopping distance of ~100 mm
Leak tests on containment vessel (pressure drop method)	< 1 x 10^{-5} bar cc/s.	Same test sensitivity for the leak tests carried out before and after the drop tests
Leak tests on SS Storage Can (helium mas spec method)	< 1 x 10^{-10} bar cc/s	Same test sensitivity for the leak tests carried out before and after the drop tests

Effect of Tests on the Package

Preliminary examination of the complete package following the test (see Figure 5) showed that the keg was significantly deformed at the point of impact but the lid was retained and the keg completely encased the containment vessel – there was no sign of leakage of the simulated contents. On disassembly, the lid was found to be trapped in place by the top skirt and it had to be levered off in order to remove the containment vessel (see Figure 5). The outer keg had to be cut away in order to remove the containment vessel (see Figure 6).

Figure 5 - Package 2816C Showing Deformation at Impact Point and Side

Figure 6 - Package 2816C Showing Keg cut away to release the Containment Vessel

Examination of the containment vessel showed that the body was dented by about 6 mm but there was no other damage to the body (see Figure 7). The head of the containment vessel was found to be severely distorted at the impact point but with the screw ring still holding the lid in place. The steel of the containment vessel although locally plastically deformed, did not show any signs of cracking.

The containment vessel closure was pressure drop leak tested and found to be leaktight with a leakage rate sensitivity of $< 1 \times 10^{-5}$ bar cc/s. This shows that the lid of the containment vessel was still held in place against the seal face of the head of the containment vessel by the screw retaining ring, despite all these components having been deformed in the drop test.

Following leak testing of the containment vessel closure, the containment vessel body was sectioned in order to extract and examine the contents, this was necessary as the deformation of the head of the containment vessel prevented removal of the screw ring and lid in the usual way (see Figure 8).

Subsequent to the test reported in this paper, a new Package 2816C was subjected to the full Type B tests; these tests showed that the containment vessel was unaffected by the tests and that the outer keg was only deformed superficially at the point of impact on the target.

Figure 7 - Containment Vessel 2851 Showing Deformation of the Head and Body

Figure 8 - Contents of Package 2816C Showing the Top of the SS Storage Cans

Effect of Tests on the Package Contents

Following removal from the containment vessel, examination of the SS Storage Cans showed that they were intact. The welded closure of both SS Storage Cans were seen to have only local deformation with no sign of other damage. It was evident that the aluminium spacers, which were seen to be only marked by the test, had provided protection to the head of the SS Storage Can. It was noted that a small buckle had been caused near the top of can # 1 (which was the upper can), presumably caused by the loading placed on can # 1 by can # 2 at impact.

The base of the SS Storage Cans were also deformed but not otherwise damaged with no sign of tearing or penetration. The base of can # 1 was indented by the aluminium spacer by about 3 mm. The side of can # 2 (near the base) was flattened - this is attributed to the secondary impact following the primary impact in the drop test in which the base end of the keg impacted the target.

The damage to both SS Storage Cans was of a nature that would not be expected to affect containment. Both the SS Storage Cans were leak tested at AERE, Harwell in a helium mass spectrometer and found to be leaktight with a leakage rate sensitivity of $< 1 \times 10^{-10}$ bar cc/s (the same as before the drop test).

Following leak testing of the SS Storage Cans the top can # 1 was stored, without opening it, for future display or examination. The base of the SS Storage Can # 2 was sawn through, the polythene bagging cut, and the 3L Bulpitt Mk II Al Can removed.

Close examination of the 3L Bulpitt Mk II Al # 2 showed that, although it was dented on the side near the base, there was no other damage, with no spillage of the contents and no damage likely to cause loss of containment (see Figure 9).

Figure 9 - Package 2816C Showing the Condition of the 3L Bulpitt Mk II Al Can following the Drop Test

SAFKEG 2816A PACKAGE DETAILS

SAFKEG 2816A Package Design

The 2816A package design is similar in design to the 2816C package having a slightly shorter keg and smaller diameter containment vessel. The 2816A package is also a general purpose container for the shipment of fissile and non-fissile material in solid (including powder) form. The 2816A packaging consists of a Keg Assembly Design No 2816, carrying a single containment vessel assembly Design No 2817 within an insulating cork liner. The assembled packaging has an overall length of 910 mm and an overall diameter of 425 mm. Calculations and an immersion test have shown that the packaging (without contents) has a density of greater than one. The tare mass of the packaging is nominally 86 kg (excluding contents). The maximum contents mass is 10 kg giving a nominal gross package mass of 96 kg. The major components of the 2816C packaging are shown in Figures 10 and 11.

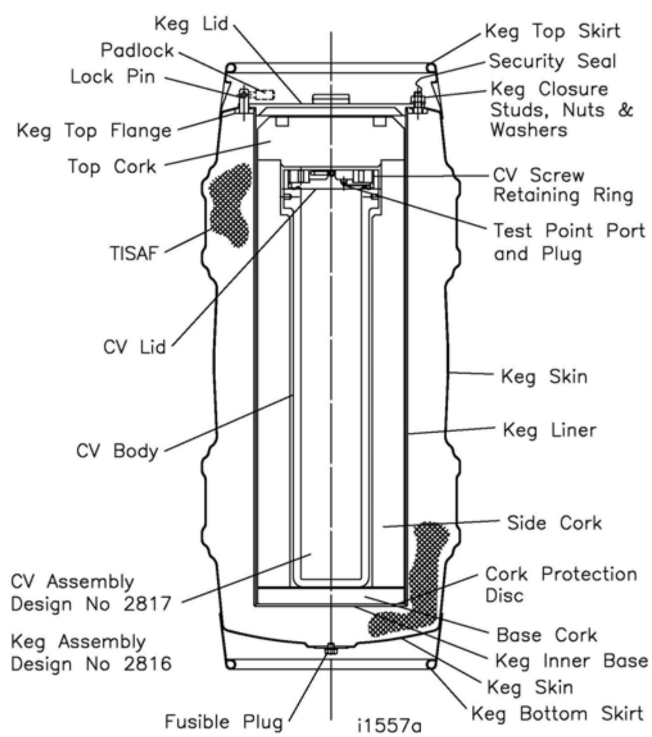


Figure 10 - SAFKEG Design No 2816A showing components and primary containers

Figure 11 - SAFKEG Design No 2816A showing the components as assembled for shipment

Component	Colloquial Name	Design N^o / Serial N^o	Overall Dim (mm)	Weight (kg)	Unit/ Package
Outer	Keg	2816/002	Ø 425x910	67	One
Inner	Containment Vessel	2817/001	Ø 148x654	15	One
Cork (top, side and base)	Cork Packing-	-	-	4	One
Packaging Assembly	SAFKEG	2816A	Ø 425x910	86	One
Contents	Tinplate Can	0564	Ø 89x191 (3½" x7½")	Negligible	Three
	Centering plywood sleeves			1	
Total contents				6	One assy
Package		2816A		93	

Test Package

The SAFKEG 2816A package used in the drop test consisted of the above components (see Figures 11) - this was a standard package unmodified for the tests, excepting only addition of the external painting to facilitate high speed cine and video recording of the package in flight.

The inner tinplate cans were completely filled with lead shot and sand with the mix adjusted to achieve a total weight of 6kg. Following sealing the lid, the tinplate cans were leak tested at AERE, Harwell by bubble immersion testing and found to be leaktight with a leakage rate sensitivity of < 1 x 10^{-5} bar cc/s.

TEST RESULTS

Test Drop Data

The drop test was carried out on the same target as that used for the 2816C tests. The drop test had been intended to be from nominally 600 m (2,000 ft) which would have ensured that the package reached terminal velocity of 61 m/s (200 ft/s) at impact, but low cloud and poor visibility forced the drop to be from 500 m (1,650 ft). The package was dropped with axis horizontal but tilted in flight (it did not spin) such that at impact it was in an attitude of 40^o from horizontal with the closure end lower than the closed end. The impact occurred near the centre of the concrete target and the package bounced several times before coming to rest, with the vertical rebound after first impact being about 6 m (20 ft).

The test data for the drop of the SAFKEG 2816A package is given below.

Parameter	Value	Comments
Drop height	335 m (1,100 ft)	
Impact velocity	61 m/s (200 ft/s, 136 mph)	About 80% of terminal velocity
Deformation of the package at impact point	~100 mm	
Estimated average impact deceleration	1,800 g	Assessed from stopping distance of ~100 mm
Leak tests on containment vessel (pressure drop method)	< 1 x 10^{-5} bar cc/s.	Same test sensitivity for the leak tests carried out before and after the drop tests
Leak tests on tinplate can	< 1 x 10^{-5} bar cc/s	Same test sensitivity for the leak tests carried out before and after the drop tests

Effect of Tests on the Package

Preliminary examination of the complete package following the test showed that the keg was severely deformed at the point of impact but the lid was retained and the keg completely encased the containment vessel – there was no sign of leakage of the simulated contents. On disassembly, the containment vessel had to be jacked out of the outer keg as it was pinched in place by the deformed keg pressing the cork onto the containment vessel body, but the keg did not have to be cut away (see Figure 12).

Examination of the containment vessel showed that the body was slightly bent but there was no other damage to the body (see Figure 13). The head of the containment vessel was found to be severely distorted at the impact point but with the screw ring still holding the lid in place. The steel of the containment vessel although deformed and locally plastically deformed, did not show any signs of cracking.

The containment vessel closure was pressure drop leak tested and found to be leaktight with a leakage rate sensitivity of < 1 x 10^{-5} bar cc/s. This shows that the lid of the containment vessel was still held in place against the seal face of the head of the containment vessel by the screw retaining ring, despite all these components having been deformed in the drop test.

Following leak testing of the containment vessel closure, the containment vessel body was sectioned in order to extract and examine the contents, this was necessary as the deformation of the head of the containment vessel prevented removal of the screw ring and lid in the usual way (see Figure 13).

Figure 12 - SAFKEG Design No 2816C

Figure 13 - Package 2816A Showing the Condition of the tinplate can following the Drop Test

Effect of Tests on the Package Contents

Following removal from the containment vessel, examination of the tinplate cans showed that there were intact, albeit with some crumpling but no splitting or breaches and no visible powder leakage. All three tinplate cans were leak tested at AERE, Harwell by bubble immersion testing and found to be leaktight with a leakage rate sensitivity of < 1 x 10^{-5} bar cc/s (the same as before the drop test).

CONCLUSIONS

The drop test of a 2816C package from a helicopter onto the concrete target demonstrated that the 2816C package provided complete containment of the contents which simulated radioactive material in powder form. In fact, all three containment barriers, the inner 3L Bulpitt Mk II Al Can, the SS Storage Can, and the containment vessel Design No 2851, provided complete containment with the inner 3L Bulpitt Mk II Al Can showing no damage likely to cause leakage (and no actual leakage) and the SS Storage Can and containment vessel Design No 2851 being leak tight to the same sensitivities as for the leak test before the drop test. Thus the containment vessel Design No 2851 was shown to provide complete containment to the same level as required for the Type B 9m drop test, and the 3L Bulpitt Mk II Al Can was shown to provide confinement to the contents (ie not proven to be leak tight, but not allowing significant leakage of the contents).

The drop test of a 2816A package from a helicopter onto the concrete target demonstrated that the 2816A package provided complete containment of the contents which simulated radioactive material in powder form. In fact, the two containment barriers, the inner tinplate can and the containment vessel Design No 2817, provided complete containment with the powder contents, showing no damage likely to cause leakage (and no actual leakage) and the tinplate cans and the containment vessel Design No 2817 being leak tight to the same sensitivities as for the leak test before the drop test. Thus the containment vessel Design No 2817 was shown to provide complete containment to the same level as required for the Type B 9m drop test, and the tinplate can was shown to provide confinement to the contents (ie not proven to be leak tight, but not allowing significant leakage of the contents).

Both tests showed that these two packages, which were designed to pass the Type B 9m drop test, performed well under the much more severe test of impacting at near terminal velocity on a concrete target, with no loss of containment. Furthermore, the tests showed that inner vessels, if packed so that there is little free space, will deform but may also provide containment of the contents. These tests showed that a well designed Type B package is likely to provide containment far beyond the regulatory test level and not show the “cliff edge” effect, that is, catastrophic failure at test levels just above the regulatory test level. Furthermore, the tests showed that relatively thin and simple inner product containers, if packed so that there is little free space, will deform but may also provide containment of the contents. Finally, the tests suggest that the Type B requirements of the IAEA regulations, which are both searching and rigorous in terms of containment of contents under severe accident conditions, are completely satisfactory in that packages designed to these requirements are likely to perform well even under extreme conditions.

REFERENCES

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