

# Helicopter drop testing of Type B packages in UK

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Testing was carried out in UK in 1986 to demonstrate the ability of two type B packages designed to pass the 9 m 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. The present paper is presented to document these tests, on packages used for the transport of radioactive materials, which have not been reported elsewhere. These data serve as a useful addition to the literature of extra regulatory testing that has been carried out on an international basis.

**Keywords:** Type B, Extended drop test, SAFKEG, Aircraft

## Introduction

As is commented in other papers presented at PATRAM 2007, 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<sup>1</sup> 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;<sup>2</sup> this was followed in 1987 by even more onerous requirements in the Murkowski Amendment.<sup>3</sup> The same concern was also raised in UK in both the nuclear industry and parliamentary committee discussions. As a result of these concerns BNFL instigated a testing programme to demonstrate the ability of Type B packages designed to pass the 9 m drop test criteria in the IAEA SS6 1985 transport regulations,<sup>4</sup> 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 nos. 2816A and 2816C), having different inner containment vessels (CVs) and contents, were drop tested from a helicopter onto an essentially unyielding concrete target. The present 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

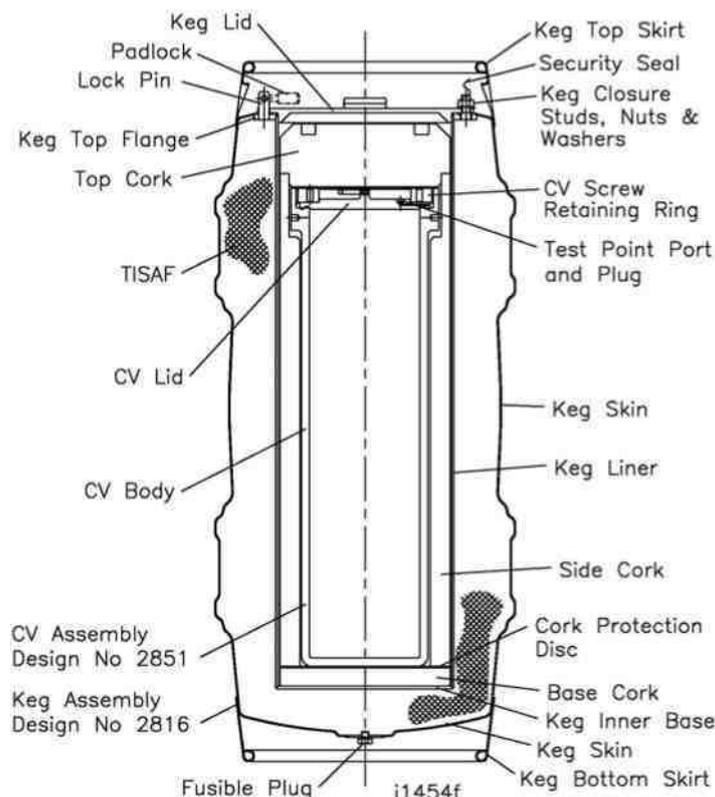
The 2816C package design is one of the Croft SAFKEG series of packages which all have an outer container (keg) based upon a stainless steel keg (similar to those used in beer kegs). This outer container is provided with a stainless steel liner, the interspace being filled with thermal insulating and shock absorbing foam (TISAF – a phenolic resin blown foam with a density of 0.45 g cc<sup>-1</sup>). The outer keg carries a single resealable leak testable stainless steel CV 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 CV assembly design no. 2851 within an insulating cork liner. The assembled packaging has an overall length of 1000 mm and an overall diameter of 425 mm. (see Table 1 for further details). 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 content mass is 25 kg giving a nominal gross package mass of 140 kg. The major components of the 2816C packaging are shown in Fig. 1 and the assembly of the contents of the CV used in the drop tests is shown in Fig. 2.

The basis of the design of the 2816C packaging is that the outer keg is designed to sacrificially protect the inner CV 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.

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1 SAFKEG design no. 2816C showing components as assembled for shipment

**Test package**

The SAFKEG 2816C package used in the drop test consisted of the following components (see Fig. 3), which 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 3 L Bulpitt Mk II Al can was completely filled with lead shot and sand with the mix adjusted to achieve a total weight of 9 kg 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<sup>-1</sup>.

**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.

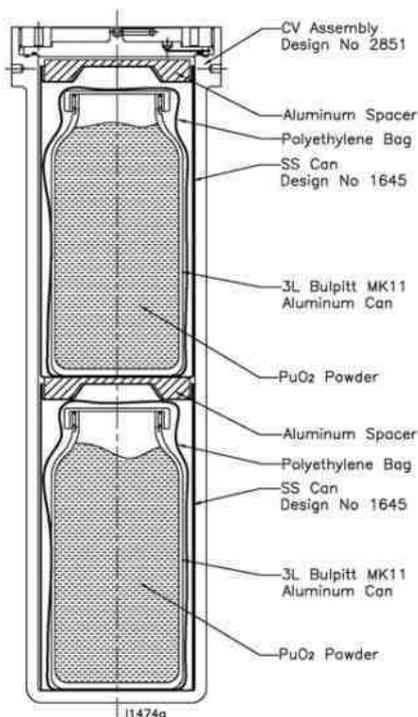
**Test results**

**Test drop data**

The drop test had been intended to be from nominally 600 m (2000 ft) which would have ensured that the package reached terminal velocity of 81 m s<sup>-1</sup> (265 ft s<sup>-1</sup>) at impact, but low cloud and poor visibility forced the drop to be from 500 m (1650 ft). The package was dropped with axis horizontal (see Fig. 4) but tilted in flight (it did not spin) such that at impact it was in an attitude of 40° 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 ~6 m (20 ft).

Table 1 Package 2816C make-up

Component	Colloquial name	Design no./serial no.	Overall diameter, mm	Weight, kg	Unit/package
Outer	Keg	2816/003	Ø425 × 1000	67	One
Inner	CV	2851/001	Ø157 × 645	43	One
Cork (top, side and base)	Cork packing	-	-	5	One
Packaging Assembly	SAFKEG	2816C	Ø425 × 1000	115	One
Contents	SS storage can	1645	Ø153 × 311	1.5	Two
	Bulpitt Mk II Al can (3 L, filled with lead shot and sand)	Design code 31	(6" × 12.25")	9	Two
	Al spacers	Design code 22	Ø131 × 285 (5.15" × 11.2")		
Total contents				Negligible	
Package		2816C		21	One assy
				136	



2 Assembly of contents in CV



3 Package 2816C components before assembly for testing



4 Package 2816C slung from helicopter before drop test

The test data for the drop of the SAFKEG 2816C package are given below (Table 2).

**Effect of tests on package**

Preliminary examination of the complete package following the test (see Fig. 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 Fig. 5). The outer keg had to be cut away in order to remove the containment vessel (see Fig. 6).

Examination of the CV showed that the body was dented by ~6 mm but there was no other damage to the body (see Fig. 7). The head of the CV 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 CV although locally plastically deformed, did not show any signs of cracking.

The CV closure was pressure drop leak tested and found to be leaktight with a leakage rate sensitivity of  $<1 \times 10^{-5}$  bar cc s<sup>-1</sup>. 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.

Table 2 Test data for drop of SAFKEG 2816C package

Parameter	Value	Comments
Drop height	500 m (1650 ft)	
Impact velocity	75 m s <sup>-1</sup> (245 ft s <sup>-1</sup> , 167 mph)	About 90% of terminal velocity
Deformation of the package at impact point	~100 mm	
Estimated average impact deceleration	2700 g	Assessed from stopping distance of ~100 mm
Leak tests on containment vessel (pressure drop method)	$<1 \times 10^{-5}$ bar cc s <sup>-1</sup>	Same test sensitivity for the leak tests carried out before and after the drop tests
Leak tests on SS storage can (helium mass spectrometer method)	$<1 \times 10^{-10}$ bar cc s <sup>-1</sup>	Same test sensitivity for the leak tests carried out before and after the drop tests



5 Package 2816C showing deformation at impact point and side

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 CV prevented removal of the screw ring and lid in the usual way (see Fig. 8).

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



7 Containment vessel 2851 showing deformation of head and body

### Effect of tests on 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



6 Package 2816C showing keg cut away to release CV



8 Contents of package 2816C showing top of SS storage cans



**9 Package 2816C showing condition of 3 L Bulpitt Mk II Al can following drop test**

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 no. 1 (which was the upper can), presumably caused by the loading placed on can no. 1 by can no. 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 no. 1 was indented by the aluminium spacer by  $\sim 3$  mm. The side of can no. 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  $s^{-1}$  (the same as that before the drop test).

Following leak testing of the SS storage cans the top can no. 1 was stored, without opening it, for future display or examination. The base of the SS storage can no. 2 was sawn through, the polythene bagging cut, and the 3 L Bulpitt Mk II Al can removed.

Close examination of the 3 L Bulpitt Mk II Al no. 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 Fig. 9).

## 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 CV. 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 (see Table 3 for further details). 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 Figs. 10 and 11.

### Test package

The SAFKEG 2816A package used in the drop test consisted of the above components (see Fig. 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 6 kg. 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  $<1 \times 10^{-5}$  bar cc  $s^{-1}$ .

## 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 (2000 ft) which would have ensured that the package reached terminal velocity of  $61 \text{ m s}^{-1}$  ( $200 \text{ ft s}^{-1}$ ) at impact, but low cloud and poor visibility forced the drop to be from 500 m (1650 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  $40^\circ$  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  $\sim 6$  m (20 ft).

The test data for the drop of the SAFKEG 2816A package are given below (Table 4).

### Effect of tests on 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

**Table 3 Package 2816A make-up**

Component	Colloquial name	Design no./serial no.	Overall diameter, mm	Weight, kg	Unit/ package
Outer	Keg	2816/002	$\text{Ø}425 \times 910$	67	One
Inner	CV	2817/001	$\text{Ø}148 \times 654$	15	One
Cork (top, side and base)	Cork packing	–	–	4	One
Packaging assembly	SAFKEG	2816A	$\text{Ø}425 \times 910$	86	One
Contents	Tinplate can	0564	$\text{Ø}89 \times 191$ (3.5" $\times$ 7.5")	Negligible	Three
	Centring plywood sleeves			1	
Total contents				6	One assy
Package		2816A		93	



10 SAFKEG design no. 2816A showing components and primary containers

and the kegel completely encased the containment vessel – there was no sign of leakage of the simulated contents. On disassembly, the CV had to be jacked out of the outer kegel as it was pinched in place by the deformed kegel pressing the cork onto the CV body, but the kegel did not have to be cut away (see Fig. 12).

Examination of the CV showed that the body was slightly bent but there was no other damage to the body

(see Fig. 13). The head of the CV 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 CV closure was pressure drop leak tested and found to be leaktight with a leakage rate sensitivity of  $<1 \times 10^{-5}$  bar cc s<sup>-1</sup>. This shows that the lid of the containment vessel was still held in place against the seal face of the head of the CV by the screw retaining ring, despite all these components having been deformed in the drop test.

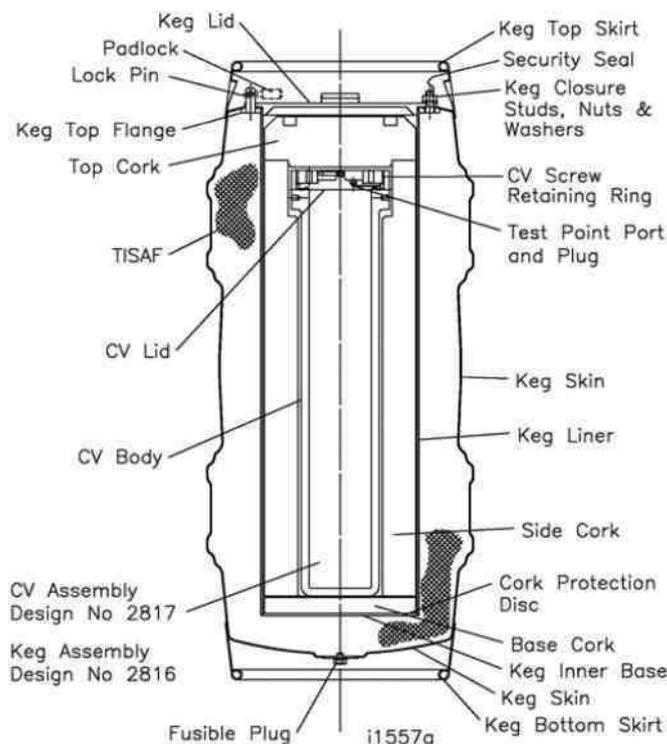
Following leak testing of the CV closure, the CV body was sectioned in order to extract and examine the contents, which was necessary as the deformation of the head of the CV prevented removal of the screw ring and lid in the usual way (see Fig. 13).

### Effect of tests on package contents

Following removal from the CV, examination of the tinplate cans showed that they 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  $<1 \times 10^{-5}$  bar cc s<sup>-1</sup> (the same as that 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 3 L Bulpitt Mk II Al can, the SS storage can, and the CV design no. 2851, provided complete containment with the inner 3 L Bulpitt Mk II Al can showing no damage likely to



11 SAFKEG design no. 2816A showing components as assembled for shipment

**Table 4 Test data for drop of SAFKEG 2816A package**

Parameter	Value	Comments
Drop height	335 m (1100 ft)	
Impact velocity	61 m s <sup>-1</sup> (200 ft s <sup>-1</sup> , 136 mph)	About 80% of terminal velocity
Deformation of the package at impact point	~100 mm	
Estimated average impact deceleration	1800 g	Assessed from stopping distance of ~100 mm
Leak tests on containment vessel (pressure drop method)	<1 × 10 <sup>-5</sup> bar cc s <sup>-1</sup>	Same test sensitivity for the leak tests carried out before and after the drop tests
Leak tests on tinplate can	<1 × 10 <sup>-5</sup> bar cc s <sup>-1</sup>	Same test sensitivity for the leak tests carried out before and after the drop tests

**12 SAFKEG design no. 2816C****13 Package 2816A showing condition of tinplate can following drop test**

cause leakage (and no actual leakage) and the SS storage can and CV design no. 2851 being leak tight to the same sensitivities as for the leak test before the drop test. Thus the CV design no. 2851 was shown to provide complete containment to the same level as required for the Type B 9 m drop test, and the 3 L Bulpitt Mk II Al can was shown to provide confinement to the contents (i.e. 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 leaktight to the same sensitivities as for the leak test before the drop test. Thus the CV design no. 2817 was shown to provide complete containment to the same level as required for the Type B 9 m drop test, and the tinplate can was shown to provide confinement to the contents (i.e. not proven to be leaktight, but not allowing significant leakage of the contents).

Both tests showed that these two packages, which were designed to pass the Type B 9 m 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.

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