



U.S. Department  
of Transportation

East Building, PHH-21  
1200 New Jersey Ave.,  
Washington, D.C. 20590

Pipeline and  
Hazardous Materials  
Safety Administration

**COMPETENT AUTHORITY CERTIFICATION  
FOR A TYPE B(U)  
RADIOACTIVE MATERIALS PACKAGE DESIGN  
CERTIFICATE USA/6788/B(U)-96, REVISION 9**

**REVALIDATION OF UNITED KINGDOM COMPETENT AUTHORITY  
CERTIFICATE GB/2799E/B(U)-96**

This certifies that the radioactive material package design described is hereby approved for use within the United States for import and export shipments only. Shipments must be made in accordance with the applicable regulations of the International Atomic Energy Agency<sup>1</sup> and the United States of America<sup>2</sup>.

1. Package Identification - 2799E Safkeg.
2. Package Description and Authorized Radioactive Contents - as described in United Kingdom Certificate of Competent Authority GB/2799E/B(U)-96, Issue 3 (attached). Contents are restricted to non-fissile or fissile excepted material.
3. General Conditions -
  - a. Each user of this certificate must have in his possession a copy of this certificate and all documents necessary to properly prepare the package for transportation. The user shall prepare the package for shipment in accordance with the documentation and applicable regulations.
  - b. Each user of this certificate, other than the original petitioner, shall register his identity in writing to the Office of Hazardous Materials Technology, (PHH-23), Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, Washington D.C. 20590-0001.
  - c. This certificate does not relieve any consignor or carrier from compliance with any requirement of the Government of any country through or into which the package is to be transported.
  - d. This certificate provides no relief from the limitations for transportation of plutonium by air in the United States as cited in the regulations of the U.S. Nuclear Regulatory Commission 10 CFR 71.88
  - e. Records of Quality Assurance activities required by Paragraph 310 of the IAEA regulations<sup>1</sup> shall be maintained and made available to authorized officials for at least three years after the last shipment authorized by this certificate. Consignors exporting shipments from the United States shall satisfy the requirements of Subpart H of 10 CFR 71.

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<sup>1</sup> "Regulations for the Safe Transport of Radioactive Materials, 1996 Edition (Revised), No. TS-R-1 (ST-1, Revised)", published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

<sup>2</sup> Title 49, Code of Federal Regulations, Parts 100 - 199, United States of America.

**CERTIFICATE USA/6788/B(U)-96, REVISION 9**

4. Special Conditions -

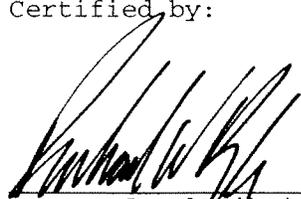
- a. The Model No. 2799E containment boundary, which is provided by the Model No. 2812 containment can, must be tested to demonstrate that the leak rate does not exceed  $1 \times 10^{-8} \text{ Pa m}^3 \text{ s}^{-1}$  standardized leak rate (or  $1 \times 10^{-7} \text{ std cm}^3/\text{s}$ ) at the following intervals: (1) within the 12-month period prior to shipment; and (2) upon replacement of the seals.
- b. Prior to each shipment, the seals of the Model No. 2812 containment can must be demonstrated to prevent leakage in excess of  $5 \times 10^{-5} \text{ Pa m}^3 \text{ s}^{-1}$  standardized leak rate (or  $5 \times 10^{-4} \text{ ref cm}^3/\text{sec}$ ).
- c. This package is authorized for transport by air. For import to, export from, domestic shipments within the United States, and transport by aircraft through the air space of the United States from a foreign nation to a foreign nation, the maximum quantity of material transported by air may not exceed an  $A_2$  quantity of plutonium in any isotope or form, as defined in 49 CFR 173.435.

5. Marking and Labeling - The package shall bear the marking USA/6788/B(U)-96 in addition to other required markings and labeling.

6. Expiration Date - This certificate expires on June 30, 2016.

This certificate is issued in accordance with paragraph 808 of the IAEA Regulations and Section 173.473 of Title 49 of the Code of Federal Regulations, in response to the November 9, 2011 petition by Croft Associates Limited, Abingdon, Oxfordshire, UK, and in consideration of other information on file in this Office.

Certified by:

  
\_\_\_\_\_  
Dr. Magdy El-Sibaie  
Associate Administrator for Hazardous Materials Safety

DEC 15 2011

\_\_\_\_\_  
(DATE)

Revision 9 - Issued to endorse United Kingdom Certificate of Approval No. GB/2799E/B(U)-96, Issue 3.



Reference: GB/2799E/B(U)-96

Issue 3

Page 1 of 7 pages

# Certificate of Approval of Package Design for the Carriage of Radioactive Materials

**THIS IS TO CERTIFY** that the Secretary of State for Transport being, for the purposes of the Regulations of the International Atomic Energy Agency, the Competent Authority of Great Britain in respect of inland surface transport and of the United Kingdom of Great Britain and Northern Ireland in respect of sea and air transport and the Department of the Environment for Northern Ireland being the Competent Authority of Northern Ireland in respect of inland surface transport, have approved the Package design as specified in section 1 of this certificate, as applied for by Croft Associates Ltd (see section 6)

as Type B(U)

by air, road, rail, sea and inland waterway

**Packaging identification: SAFKEG**

Packages manufactured to this design meet the requirements of the regulations and codes on page 2, relevant to the mode of transport, subject to the following general condition and to the conditions in the succeeding pages of this certificate.

In the event of any alteration in the composition of the package, the package design, the quality assurance programme(s) associated with the package or in any of the facts stated in the application for approval, this certificate will cease to have effect unless the Competent Authority is notified of the alteration and the Competent Authority confirms the certificate notwithstanding the alteration.

**Expiry Date:** This certificate is valid until the end of June 2016

## COMPETENT AUTHORITY IDENTIFICATION MARK:

Type B(U)  
GB/2799E/B(U)-96



Transport Radiological Adviser  
Department for Transport  
Great Minster House  
76 Marsham Street  
London SW1P 4DR

*On behalf of the Secretary of State for Transport,  
and the Department of the Environment for Northern Ireland*

**This certificate does not relieve the consignor from compliance with any requirement of the government of any country through or into which the package will be transported.**

Serial No.11/037

REGULATIONS AND CODES OF PRACTICE GOVERNING THE TRANSPORT OF RADIOACTIVE MATERIALS

**INTERNATIONAL**

International Atomic Energy Agency (IAEA)

TS-R-1 Regulations for the Safe Transport of Radioactive Materials 2005 or 2009 Editions.

International Maritime Organisation (IMO)

International Maritime Dangerous Goods (IMDG) Code Amendment 34-08.

International Civil Aviation Organisation (ICAO)

Technical Instructions for the Safe Transport of Dangerous Goods by Air 2011-2012 Edition.

United Nations Economic Commission for Europe (UNECE)

European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) 2009 Edition (to end June 2011); *or*

European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) 2011 Edition

Intergovernmental Organisation for International Carriage by Rail (OTIF)

Convention concerning International Carriage by Rail (COTIF) Appendix C. Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) 2009 Edition (to end June 2011); *or*

Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) 2011 Edition

**UNITED KINGDOM**

**ROAD**

GREAT BRITAIN ONLY.

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009, SI 2009 No 1348.

NORTHERN IRELAND ONLY.

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2010, SR 2010 No 160.

**RAIL**

GREAT BRITAIN ONLY.

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009, SI 2009 No 1348.

**SEA**

British registered ships. All other ships whilst in United Kingdom territorial waters. The Merchant Shipping (Dangerous Goods and Marine Pollutants) Regulations 1997, SI 1997 No 2367; Merchant Shipping Notice No MSN 1820 M, "The Carriage of Dangerous Goods and Marine Pollutants in Packaged Form - Amendment 34-08 to the International Maritime Dangerous Goods (IMDG) Code".

**AIR**

The Air Navigation Order 2009, SI 2009 No 3015. The Air Navigation (Dangerous Goods) Regulations 2002, SI 2002 No 2786. The Air Navigation (Dangerous Goods) (Amendment) Regulations 2009, SI 2009 No 1492. Official Record Series 4 No. 845 Air Navigation (Dangerous Goods) Regulations 2002 General Exemption.

## 1. PACKAGE DESIGN SPECIFICATION

The Package Design Specification shall be in accordance with Croft Associates Ltd's Safety Report reference DSR 2799E-96 Issue H dated 15 June 2011, and modifications to the package design approved by the authority named on page 1 of this certificate under the established modifications procedure.

### 1.1 Specification of Design

Design No.	Title (number of components)	Drawing / Drawing List	Issue
2799E	Outer / Keg (one)	DL-1C-5407	D
2812	Inner / Containment can (one)	DL-1C-1534	P

### 1.2 Authorised Contents

- Generalised content type. Uranium and/or plutonium metal, compounds and/or mixtures, non-fissile alpha emitting isotopes and neutron sources such as Pu/Be, Am/Be or Cf. Fissile material is limited to fissile exempt quantities. See Package Contents Specification PCS 008 Issue V for details
- The content limit for the radioactive material to be carried is 10,000 grams. The content limit for the package (radioactive material + other material + packaging) is 11,500 grams
- The physical form of the nuclides shall be solid as powder, dried cake, sintered pellets or metal pieces
- The chemical form of the nuclides shall be either elemental or compound form
- The total rate of heat generation shall not exceed 10W
- The total activity limits of the content are specified in PCS 008 Issue V

### 1.3 Fissile Material Restrictions

The contents of the package and/or consignment meet the requirements of paragraph 417 of IAEA TS-R-1 2009 Edition

### 1.4 Package Dimensions and Weights

- Nominal Dimensions: 425mm diameter x 540mm high (see section 5 for package illustration)
- Maximum authorised gross weight: 67.5 kg (including 11.5 kg of maximum content)

## 2. USE OF PACKAGE

### 2.1 Use of packaging

- The packaging shall be used, handled and maintained in accordance CPI 013 Issue O (Packing and Handling Instructions for Package Design No 2799E) and CSP 006 Issue I (Serviceability checks on Package Design No 2799E).

## 2.2 Supplementary Operational Controls

- a) The accessible surfaces of the package must not exceed 85°C. Suitable measures (such as the use of a light metal canopy to prevent access to the package surface) must be taken to ensure that no access can be gained to surfaces with a temperature in excess of 85°C.
- b) Special stowage provisions are not required as the maximum surface heat flux does not exceed 15 W/m<sup>2</sup>

## 2.3 Actions prior to shipment

- a) Administrative controls shall ensure that the contents are in accordance with section 1 of this certificate, and that the consignor and consignee hold a copy of the instructions on the use of the packaging.

## 2.4 Emergency Arrangements

- a) Before shipment takes place, the consignor shall have drawn up suitable emergency plans, copies of which shall be supplied to the UK Competent Authority on demand.
- b) Within the UK the RADSAFE scheme will be used
- c) If the consignor's own, or other approved emergency plans cannot be initiated, for any reason, then the police shall be informed immediately and requested to call the local NAIR (National Arrangements for Incidents involving Radioactivity) establishment.

## 2.5 Ambient temperature range for package design

- a) -40°C to +38°C

## 2.6 Statement of Compliance with IAEA TS-R-1 2009 Edition paragraphs 637, 653-655 and 658-664

- a) The package design complies
- b) The package maximum normal operating pressure does not exceed 700 kPa (gauge)
- c) The accessible surfaces of the package do not exceed 85°C. See Section 2.2.

## 3. QUALITY ASSURANCE

3.1 The quality assurance programmes assessed as adequate in relation to this design by the authority named on page 1 of this certificate, at the date of issue, are as specified in Croft Associates Ltd's Safety Report reference DSR 2799E-96 Issue H, and comprise the following:

- a) Croft Associates Ltd Quality Management System; and

- b) any other quality assurance programmes for design; testing; manufacture; documentation; use; maintenance and inspection; and transport and in-transit storage operations, providing they comply with national or international standards for quality assurance agreed as acceptable by the authority named on page 1 of this certificate.
- 3.2 Any quality assurance programmes not made available for assessment by the authority named on page 1 of this certificate prior to the date of issue of this certificate and applicable to any stage of design; testing; manufacture; documentation; use; maintenance and inspection; and transport and in-transit storage operations, must, prior to their implementation or use, be submitted to and confirmed as adequate by the authority named on page 1 of this certificate.
- 3.3 No alteration may be made to any quality assurance programme(s) confirmed as adequate in relation to this design, unless:
- a) the authority named on page 1 has confirmed the amended QA programme is adequate prior to implementation or use; or
  - b) the alteration falls within the agreed change control procedures set out in the programme(s)

#### **4. ADMINISTRATIVE INFORMATION**

##### **4.1 Other related certificates (alternative radioactive contents)**

No other related certificates exist.

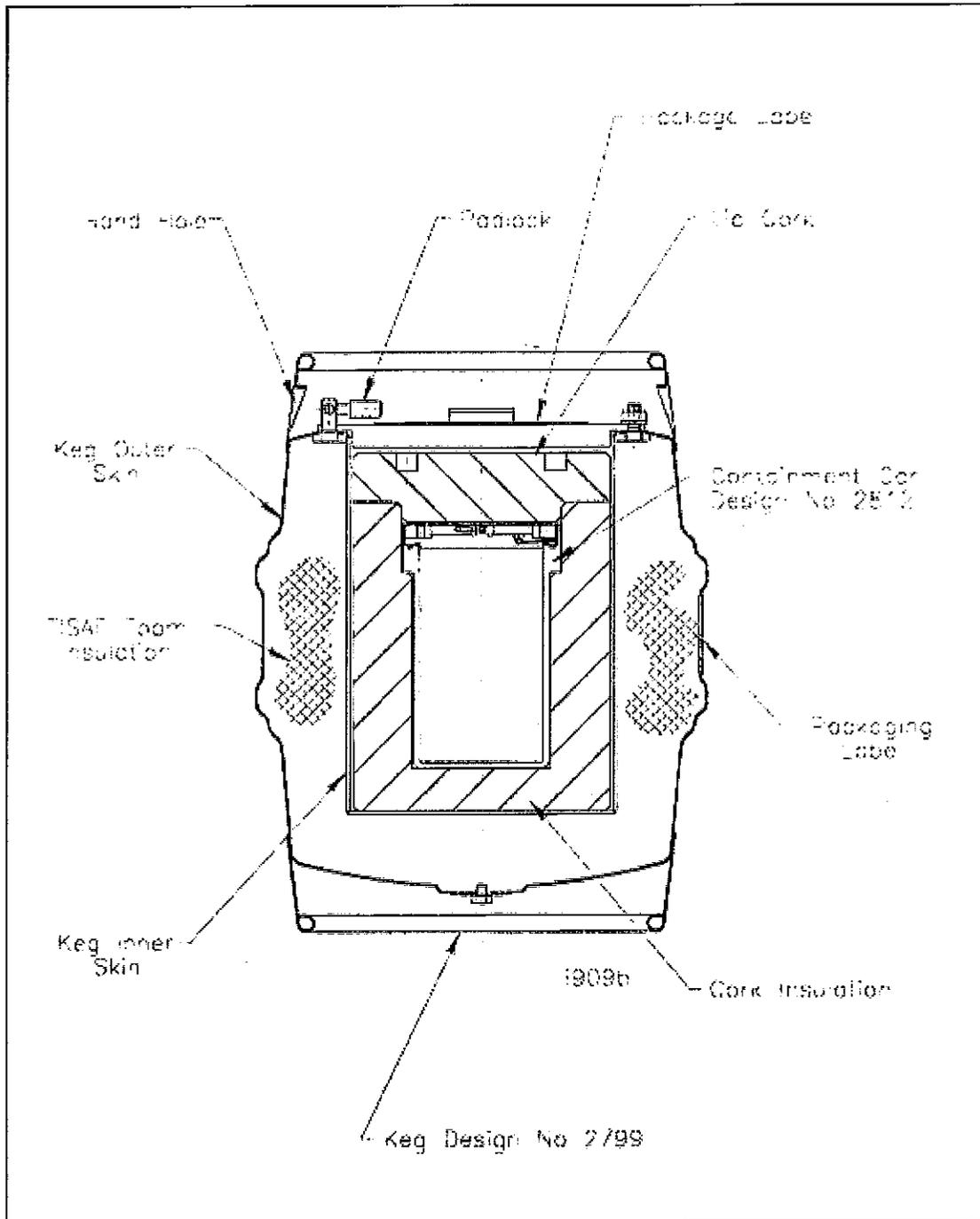
##### **4.2 Additional Technical Data / Information**

- a) At the time of compilation of this design approval certificate, The Ionising Radiations Regulations 1999, SI 1999 No 3232 and Approved Code of Practice apply, with regard to radiation protection, to all modes of transport and The Dangerous Substances in Harbour Areas Regulations 1987, SI 1987 No 37, apply in GB Ports

##### **4.3 Shipment Approval**

- a) Packages meeting this design that contain over 3000 A<sub>2</sub>, or 1000 TBq, whichever is the lower, shall require multilateral shipment approval

5. PACKAGE ILLUSTRATION



**6. CERTIFICATE STATUS**

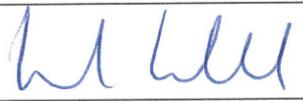
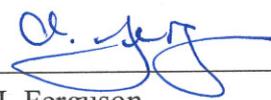
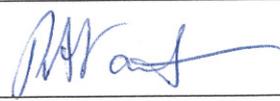
Design Approval issued to:-  
 Croft Associates Ltd  
 F4 Culham Science Centre  
 Abingdon  
 Oxfordshire  
 OX14 3DB  
 United Kingdom

Issue No.	Date of Issue	Date of Expiry	Reason for Revision
GB/2799E/B(U)-96 Issue 3	As on page 1	30 June 2016	Renewal
GB/2799E/B(U)-96 Issue 2	5 March 2008	30 June 2010	Renewal with minor changes (1 year extension issued on 21 June 2010)
GB/2799E/B(U)-96 Issue 1	24 June 2004	30 June 2007	Design approval issued under new regulations; Fissile contents removed; and minor amendments/clarification.
GB/2799E/B(U)F-85 Issue 4	18 June 2001	31 March 2004	Renewal

## Package Contents Specification

for

## Package Design No 2799E

Title	Package Contents Specification for Package Design No 2799E	Number	PCS 008
		Issue	<b>V</b>
		File Reference	PCS 008-V-96-Package Contents Specification 2799E.docx
Compiled		Checked	
	S H Marshall		A L Ferguson
Approved		Date	15/6/4
	R A Vaughan		
Croft Associates Ltd, F4 Culham Science Centre, Abingdon, Oxon, OX14 3DB UK Tel +44 (0)1865 407740			

## **1 Introduction**

The 2799E package design is one of the Croft SAFKEG series of packages that all have an outer container that uses a stainless steel keg (similar to those used in beer kegs) which is provided with a stainless steel liner, the interspace being filled with TISAF (Thermal Insulating and Shock Absorbing Foam – a phenolic resin blown foam). The outer keg carries a single resealable, leak-testable stainless steel containment vessel within cork packing.

The 2799E package is a general purpose container for the shipment of non-fissile and fissile excepted material in solid form. The packaging consists of a Keg Assembly Design No 2799, carrying a single Containment Vessel (CV) Assembly Design No 2812.

This report assesses the limiting criterion for the radionuclides to be transported as detailed in table 2, to ensure compliance with the IAEA TS-R-1 transport Regulations [Ref 1], and identifies the package limit for each nuclide.

## **2 Specification of Contents**

### **2.1 General nature of content**

The contents may be non fissile or fissile excepted alpha, beta or gamma emitting isotopes, for example uranium, plutonium, americium and thorium in compound form or mixtures. Or the contents may be neutron sources of Pu/Be, Am mixed with beryllium, boron, lithium or fluorine or Californium 252.

### **2.2 Radionuclides**

See Table 2. Associated daughter products are also allowed, however, any daughter products that do not provide a significant contribution to the limits shown are not listed.

Maximum enrichment for U235 shall be 100% by weight.

### **2.3 Physical state**

Solids as powder, dried cake, metal pieces or sintered pellets.

Powders shall have been produced by normal techniques and not have been further processed to produce specifically fine powder.

### **2.4 Chemical composition**

Elemental or compound form.

### **2.5 Quantity**

Maximum quantity of radioactive material to be carried is 10,000 g. The contents limit for the package (radioactive material + other materials + packing) is 11,500 g.

## 2.6 Activity Limit

### 2.6.1 Individual Radionuclide Limits

The package limits for individual nuclides for land, sea and air are given in Table 2 under the column headed “Package Limit”.

### 2.6.2 Limits for Mixtures of Radionuclides

Where more than one nuclide is present, the contents are limited as below:

- Mixtures of the nuclides given in Table 1, which are individually limited by the Package Limit, are limited such that the sum of the proportionate amounts of each nuclide with respect to the quantity shown does not exceed unity.
- Content activity to be limited so that the total heat emission for a single package is less than 10 W
- Neutron emitters such as Cf 252 must not be carried with any fissile material
- Trace quantities of other radionuclides (other than those listed in Table 1) may be carried providing that their individual activities do not exceed 1% of the total activity of the contents.

## 2.7 Fissile Material Consignment limit [672]

For fissile material a mass limit per consignment will be applied such that:

$$\frac{\text{mass of uranium-235 (g)}}{X} + \frac{\text{mass of other fissile material (g)}}{Y} < 1$$

where X and Y are the mass limits defined below in table 1.

Fissile material	Fissile material mass (g) mixed with substances having an average hydrogen density less than or equal to water	Fissile material mass (g) mixed with substances having an average hydrogen density greater than water
Uranium 235 (X)	400	290
Other fissile material (Y)	250	180

**Table 1 – Consignment Mass Limits for Exceptions from the Requirements for Packages Containing Fissile Material (Ref 1)**

However these limits may only be applied when:

- i. Each individual package contains not more than 15g of fissile material;
- ii. Neither beryllium nor deuterium shall be present in quantities exceeding 1% of the applicable consignment mass limits provided in Table 1.

## **2.8 Primary containers and packing**

Primary containers may be polythene bottles and/or heat seal 'bags' which may then be placed in metal cans. The neutron sources of Am/(mixed with either Be, F, B or Li) and Cf 252 are packed in welded **steel** capsules.

If the solid radioactive material is (or may be) soluble in or leachable by water, a sachet of dry silica gel (not less than 10 g) must be packaged with the primary containers within the resealable stainless steel containment can (design No 2812).

## **3 Calculation of Allowable Content**

### **3.1 Criticality limit**

Contents are restricted to fissile excepted quantities.

### **3.2 Heat Limits**

The heat limit has been set at 10W (1,690 MeV Ci). This heat load has been shown to produce acceptable temperatures in the packaging under the most restrictive assumptions required by the regulations.

### **3.3 Shielding Limit**

The contents listed in Table 2 are primarily alpha or beta emitters for which the shielding provided by the stainless steel cans is sufficient to allow unlimited contents without external surface dose or TI (radiation level at 1 m from the external surface of the package) exceeding the regulatory limits.

The only nuclides which produce a significant gamma or neutron dose, either directly or from daughters, are  $^{241}\text{Pu}$ , **227Ac**,  $^{241}\text{Am}$ ,  $^{243}\text{Am}$ ,  $^{232}\text{U}$ , Am/(mixed with either Be, F, B or Li), Cf and Pu/Be (sources). The quantities of these materials have been limited to ensure that the external radiation dose levels are within the regulatory limits.

When  $^{243}\text{Am}$  or **227Ac** is carried a suitable lead pot must be used, see detailed instructions in CPI 013. The mass of contents and pot shall not exceed 11,500g as specified in 1.5 above.

### **3.4 Mass Limit**

An arbitrary maximum mass for the package radioactive contents, and therefore any single nuclide, is set at 10,000 g. Lower mass limits for some nuclides are specified where these are more realistic.

$^{241}\text{Pu}$  is limited to 10% of the Pu limit as this is the upper limit for  $^{241}\text{Pu}$  in Pu (with a margin of safety).

$^{232}\text{U}$  is limited to  $10^{-4}$  % of U limit as this is the upper limit for  $^{232}\text{U}$  in U (with a margin of safety).

### **3.5 Package Limit**

The activity limits for individual nuclides for the different criteria of criticality, heat output, radiation shielding and mass, are as listed in Table 2. The maximum activity of each nuclide that may be carried in the package is chosen as the least of the separate limits listed in Table 2.

## **4 References**

1. International Atomic Energy Agency, IAEA Safety Standards Series No TS-R-1, Regulations for the Safe Transport of Radioactive Material, 2009 Edition
2. Croft Associates Ltd, CTR 83/3, Heat Generation by the decay of radioactive isotopes, Issue F.
3. Croft Associates Ltd, CS 2000/18, Package 2799E – Dose Rates due to Neutron Emitters, Issue C
4. Croft Associates Ltd, CS 2000/19, Package 2799E – Dose Rate and heat output from Americium-243, Issue A
5. Grove Engineering, USA, Microshield Version 6.02 and 8.03, Analysis of Shielding and exposure to gamma Radiation.
6. Croft Associates Ltd, CS 2010/12, Package 2799E – Strontium 90 Shielding Calculations for the 2799E Package, Issue A
7. Croft Associates Limited, CS 2011/02, Actinium 227 Shielding Calculations for the 2799E Package, Issue A

**Table 2 - Package Contents Limits**

Fissile Nuclides		TS-R-1 A <sub>2</sub> value (Bq)	Specific Activity [2] (Bq/g)	Criticality Limit (g) (Bq)		Heat Limit		Shielding Limit (Bq)	Mass limit (g) (Bq)		Package limit			
						Heat Output [1] (W/Bq)	Activity for 10W (Bq)				Land and sea transport (g) (Bq)		Air transport TS-R-1 Air limit (3000 A <sub>2</sub> ) (g) (Bq)	
<sup>239</sup> Pu	Plutonium	1.000E+09	2.301E+09	15.00	3.452E+10	8.100E-13	1.235E+13	Infinite	15.0	3.45E+10	15.0	3.45E+10	15.0	3.45E+10
<sup>241</sup> Pu	Plutonium	6.000E+10	3.814E+12	7.50	2.861E+13	3.240E-15	3.086E+15	Mass limit	1.5	5.72E+12	1.5	5.72E+12	1.5	5.72E+12
<sup>233</sup> U	Uranium	6.000E+09	3.584E+08	15.00	5.377E+09	7.560E-13	1.323E+13	Infinite	15.0	5.38E+09	15.0	5.38E+09	15.0	5.38E+09
<sup>235</sup> U	Uranium	U	8.001E+04	15.00	1.200E+06	7.020E-13	1.425E+13	Infinite	15.0	1.20E+07	15.0	1.20E+06	15.0	1.20E+06
<sup>239</sup> Pu/Be	Pu/Be [3]	1.000E+09	2.301E+09	15.00	3.452E+10	8.100E-13	1.235E+13	9.730E+10	15.0	3.45E+10	15.0	3.45E+10	15.0	3.45E+10
Non-fissile Nuclides														
<sup>252</sup> Cf	Californium [3]	3.000E+09	1.994E+13		NA	9.510E-13	1.052E+13	4.980E+10	1.00E-02	1.99E+11	2.5E-03	4.98E+10	2.5E-03	4.98E+10
<sup>238</sup> Pu	Plutonium	1.000E+09	6.339E+11		NA	8.910E-13	1.122E+13	Infinite	75.0	4.75E+13	17.7	1.12E+13	4.7	3.00E+12
<sup>240</sup> Pu	Plutonium	1.000E+09	8.435E+09		NA	8.370E-13	1.195E+13	Infinite	75.0	6.33E+11	75.0	6.33E+11	75.0	6.33E+11
<sup>242</sup> Pu	Plutonium	1.000E+09	1.453E+08		NA	7.830E-13	1.277E+13	Infinite	75.0	1.09E+10	75.0	1.09E+10	75.0	1.09E+10
<sup>232</sup> U	Uranium	1.000E+09	7.923E+11		NA	8.370E-13	1.195E+13	4.440E+08	1.50E-03	1.19E+09	5.60E-04	4.44E+08	5.60E-04	4.44E+08
<sup>234</sup> U	Uranium	6.000E+09	2.313E+08		NA	7.560E-13	1.323E+13	Infinite	1.50E+02	3.47E+10	1.50E+02	3.47E+10	1.50E+02	3.47E+10
<sup>236</sup> U	Uranium	6.000E+09	2.395E+06		NA	6.750E-13	1.481E+13	Infinite	1.50E+02	3.59E+08	1.50E+02	3.59E+08	1.50E+02	3.59E+08
<sup>238</sup> U	Uranium	U	1.245E+04		NA	6.750E-13	1.481E+13	Infinite	1.00E+04	1.24E+08	1.00E+04	1.24E+08	1.00E+04	1.24E+08
<sup>241</sup> Am	Americium	1.000E+09	1.271E+11	88.00	NA	8.910E-13	1.122E+13	2.770E+13	8.80E+01	1.12E+13	8.80E+01	1.12E+13	2.36E+01	3.00E+12
<sup>243</sup> Am	Americium [4] (in 10mm lead pot)	1.000E+09	7.382E+09		NA	1.517E-11	6.592E+11	1.218E+12	8.80E+01	6.50E+11	8.80E+01	6.50E+11	8.80E+01	6.50E+11
<sup>241</sup> Am/Be	Americium / Beryllium [3]	1.000E+09	1.271E+11	88.00	NA	8.910E-13	1.122E+13	9.730E+10	8.80E+01	1.12E+13	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>241</sup> Am/B	Americium / Boron [3]	1.000E+09	1.271E+11	88.00	NA	8.910E-13	1.122E+13	9.730E+10	8.80E+01	1.12E+13	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>241</sup> Am/Li	Americium / Lithium [3]	1.000E+09	1.271E+11	88.00	NA	8.910E-13	1.122E+13	9.730E+10	8.00E+00	1.02E+12	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>241</sup> Am/F	Americium / Fluorine [3]	1.000E+09	1.271E+11	88.00	NA	8.910E-13	1.122E+13	9.730E+10	8.80E+01	1.12E+13	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>241</sup> Am/ <sup>243</sup> Am/Be	Americium / Beryllium [3]	1.000E+09	1.271E+11		NA	8.910E-13	1.122E+13	9.730E+10	8.80E+01	1.12E+13	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>241</sup> Am/ <sup>243</sup> Am/B	Americium / Boron [3]	1.000E+09	1.271E+11		NA	8.910E-13	1.122E+13	9.730E+10	8.80E+01	1.12E+13	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>241</sup> Am/ <sup>243</sup> Am/Li	Americium / Lithium [3]	1.000E+09	1.271E+11		NA	8.910E-13	1.122E+13	9.730E+10	8.80E+01	1.12E+13	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>241</sup> Am/ <sup>243</sup> Am/F	Americium / Fluorine [3]	1.000E+09	1.271E+11		NA	8.910E-13	1.122E+13	9.730E+10	8.80E+01	1.12E+13	7.66E-01	9.73E+10	7.66E-01	9.73E+10
<sup>237</sup> Np	Neptunium	2.000E+09	2.610E+07	300.00	NA	1.020E-12	9.804E+12	4.250E+09	7.83E+09	2.04E+17	1.63E+02	4.25E+09	1.63E+02	4.25E+09
<sup>90</sup> Sr [6]	Strontium	3.000E+11	5.051E+12		NA	1.810E-13	5.525E+13	4.96E+10	1.00E+04	5.05E+16	9.82E-03	4.96E+10	9.82E-03	4.96E+10
<sup>232</sup> Th	Thorium	U	4.061E+03		NA	6.430E-13	1.555E+13	Mass limit	1.00E+04	4.06E+07	1.00E+04	4.06E+07	1.00E+04	4.06E+07
<sup>244</sup> Cm	Curium	2.000E+09	2.996E+12		NA	9.300E-13	1.075E+13	Infinite	1.00E+04	3.00E+16	3.59E+00	1.08E+13	2.00E+00	6.00E+12
<sup>63</sup> Ni [5]	Nickel	3.000E+13	2.192E+12		NA	2.745E-15	3.644E+15	Mass limit	1.00E+04	2.19E+16	1.66E+03	3.64E+15	1.66E+03	3.64E+15
<sup>227</sup> Ac [7]	Actinium	9.000E+07	2.682E+12		NA	1.270E-14	7.874E+14	8.000E+10	6.00E+03	1.61E+16	2.98E-02	8.00E+10	2.98E-02	8.00E+10

[1] Croft Associates Ltd CTR 83/3, Heat generation by the decay of radioactive isotopes, Issue F dated 16/6/1988

[2] IAEA TS-G-1.1, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, para 240

[3] Croft Associates Ltd, CS 2000/18, Package 2799E - Dose rates due to neutron emitters, Issue C

[4] Croft Associates Ltd, CS 2000/19, Package 2799E - Dose rate and heat output from Am-243, Issue B

[5] Heat rate derived using Microshield Code V7.02, Grove Software Inc.

[6] Croft Associates Ltd, CS 2010/12, Package 2799E - Strontium 90 Shielding Calculations for the 2799E Package

[7] Croft Associates Ltd, CS 2011/02, Ac-227 Shielding Calculations for the 2799E Package



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