IAEA SELF ASSESSMENT PACKAGE TYPES
METHODS FOR LEAK TESTING

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ABSTRACT

In preparation for TRANSCC 18 in 2009 several aspects of leak test methods and their associated pass/fail criteria for Industrial and Type A packagings (ie non Competent Authority Approved packages) were discussed and proposals submitted to change the criteria. It emerged that whilst there was existing guidance on this subject and that the regulations specified 'no loss' the practicalities of testing had not been addressed sufficiently, since 'no loss' was not a justifiable pass criteria. It was suggested that a briefing paper should be produced to present what the current leak testing practice was for packages that do not require Competent Authority approval (Excepted, IP-1,2 ,3 & Type A). The paper below forms the spine of that briefing paper and draws on the experience of Gravatom and LLW Repository for the testing of such package types.
The paper considers and describes;

- the existing regulatory status and the associated guidance;
- qualitative methods including liquid immersion/bubble detection, pressure and particulate simulant;
- the applicability of methods for a range of designs including vials, drums, boxes and Freight Containers;
- the accuracy, advantages, practicality and limitations of the qualitative methods presented;
- the relationship of such methods to package types permitted to be used under the alternative arrangements for IP-2/3 package types e.g.UN tested packagings
- economics of the methods

The paper will then describe several case studies based on a range of packaging, e.g Type A liquid vial packages, IP-2 Freight Containers etc.

1 INTRODUCTION

Following the UK DfT stakeholders meeting In preparation for TRANSCC 18 in 2009 several aspects of leak test methods and their associated pass/fail criteria for Industrial and Type A packaging (i.e. self assessment package types) were discussed and proposals submitted to change the criteria.
Any change in the criteria has to be carefully considered in order that the principles and practices employed by the industry in the past are thoroughly reviewed for their continued suitability. Furthermore it is important that the following aspects are taken in account;

Public perception – the public have been told that because contents are limited the Excepted, Industrial and Type A packages are safe because their contents are limited therefore simply adding another limit is perhaps implying they are not as safe as first thought.
Raising standards unnecessarily higher and will it lead to pre-shipment leak testing of Excepted, Industrial and Type A packages?
Consequences of raising standards may result in the exclusion of some cost effective package designs that hold credible safety records.
Reviewing industry practice may be all that is required to provide standards for testing
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It is recognised also that a criteria for self assessment package types is perhaps overdue so it should be noted that this paper represents the experience of Gravatom and the LLW Repoitory and although this reflects the experience of a fairly broad section of the industry not all aspects have been covered.

Also in the interests of brevity excluded are those packages not subject to the testing for normal conditions of transport, although paragraph 615 implies some demonstration/assessment of leak tightness under routine conditions is necessary as part of the package assessment.

2 EXISTING REGULATORY STATUS AND THE ASSOCIATED GUIDANCE

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From TS-R-1 2009 (May 2009 Version),the regulatory requirements are as follows;

Industrial Packages Type 2	Type A Packages
622. A *package* to be qualified as a *Type IP-2* shall be designed to meet the requirements for *Type IP-1* as specified in para. 621 and, in addition, if it were subjected to the tests specified in paras 722 and 723, it would prevent: (a) Loss or dispersal of the radioactive contents; and (b) More than a 20% increase in the maximum *radiation level* at any external surface of the *package*.	646.A *package* shall be so designed that if it were subjected to the tests specified in paras 719–724, it would prevent: (a) Loss or dispersal of the radioactive contents; and (b) More than a 20% increase in the maximum *radiation level* at any external surface of the *package*.

The corresponding guidance in TS-G-1.1 2008 is a follows;
Requirements for industrial package Type 2 (Type IP-2) and Type A (Abbreviated)

622.1. Consideration of the release of contents from Type IP-2 packages imposes a containment function on the package for normal conditions of transport. Some simplification in demonstrating no loss or dispersal of contents is possible owing to the rather immobile character of some LSA material and SCO contents and the limited specific activity and surface contamination. See also paras 646.2–646.5.

646.1. The design of, and contents limits imposed upon, **Type A packages intrinsically limit** any possible radiological hazard. This.... so as to ensure safety.

646.2. A maximum **allowable leakage rate for the normal transport of Type A packages has never been defined quantitatively** ...... but it has always been required in a practical sense.

646.3. Practically, ... that exist. A qualitative approach, ... may be employed. In applying the preferred test method the maximum differential pressure used should be that resulting from the contents and the expected ambient conditions. The intent of paras 619, 622(a), 646(a) and 649 is **to ensure that under normal transport conditions the radioactive contents of the package cannot escape in quantities that may create a radiological or contamination hazard**.

646.4. For solid, granular and liquid contents, one way of satisfying the requirements for ‘no loss or dispersal’ **would be to monitor the package (containing a non-active, control material) on completion of a vacuum test** or other appropriate tests to determine visually whether any of the contents have escaped. For liquids, **an absorbent material may be used as a test indicator**. Thereafter, a careful **visual inspection** of the package may confirm that its integrity is maintained and no leakage has occurred. Another .... any leakage has occurred.

646.5. For gaseous contents, ... paths exist. **Another detection method would be a simple bubble test.**

The key statements are shown in bold text. Paragraph 646.2. appears to accept the impracticality of the no loss concept and looks to the industry and the Competent Authorities to interpret and use their own methods to demonstrate containment integrity.

3 CURRENT LEAK TESTING PRACTICE

Wherever possible current practice is to use qualitative proven methods such as soap bubble/water immersion tests pre and post impact, sometimes with a reduced pressure differential for industrial packages. However these methods do not show if there is a transient leak of short duration upon impact as the package closure elastically deforms (sometimes colloquially described as ‘seal burp’). A tracer simulant is needed for this. Furthermore the practice has always been to keep the test methods simple and cost effective.

The UK Transport Container Standardisation Committee authored Transport of Radioactive Material Code of Practice TCSC1068 December 2005; “Leakage tests on packages for transport of radioactive materials” contains comprehensive guidance on the methods for leak testing. These range in complexity from simple bubble detection (qualitative and detects leak rates of 10^{-4} Pa m^3 s^{-1} and greater) using immersion or soap solution to helium sniff testing using calibrated leaks (qualitative and detects leak rates of 10^{-7} Pa m^3 s^{-1} and greater). Quantitative methods include gas pressure drops in seal spaces or package cavities with sensitivities of 10^{-7} Pa m^3 s^{-1}. It must be noted that none of these tests are suitable for detecting transient leaks during an impact.

For the majority of IP-2 packages immersion tests are not always practical due to their size (consider a 210 litre drum) and tests requiring pressure differentials of 1 bar are not possible due to the thin package wall thickness. Consequently the use of liquid or powder simulants can be used, these can be introduced during the build of the test specimen and their presence or otherwise detected visually or by using detection equipment both during and after impact.

Type A packages vary widely from unshielded fabricated containments in drums, lead/steel composite flasks to simple glass vials in polystyrene lined fibreboard boxes. For unshielded or shielded it is usually not difficult to introduce a leak test point on the test specimen and use a soap bubble test. Type As are typically expected to be transported by all modes of transport and therefore must retain contents at a pressure differential of 95kPa to meet the requirements of air transport, so this rarely presents a problem. Leak tests can be conducted pre and post impact with little difficulty, if transient leakage is anticipated then simulant can be used to detect this in most cases.

3 COST IMPACT OF LEAK TESTING

The cost implications of leak test methods for the development of self assessment package types must be taken seriously as these designs are not subject to Competent Authority Approval and the leak integrity must be considered in the package design and justification practices. For example package design requiring leak tested using ;

- Helium gas or other tracer gas, will require the use of a gas spectrometer (associated calibration and maintenance) with with skilled operators with a high initial cost outlay
- Pressure fall method require skilled staff but the equipment used (air pumps and digital manometers) are marginally inexpensive.
- Soap bubble method require skilled operators but the soap solutions are readily available and are inexpensive.
- Powder simulants for seal burp testing are, if treated with fluorescent dyes, expensive but a only few grammes are required
- Liquid dyes for absorbent paper leak test method are commercially available and are inexpensive

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4 ACCURACY OF CURRENT PRACTICE

For the purposes of comparison only to obtain a defined quantity of 'acceptable' release this section uses the maximum permitted contents of an excepted package as a comparator. This is because the radioactive contents of an excepted package are limited so that in the event of total loss of the contents no significant radiological hazard would arise.

Consider a drum of LSA-II SOLID material containing soil contaminated with any isotope.

The LSA II limit for solids from paragraph 409 is 10^{-4} Bq/g and from TS-R1 table 5 the excepted package limits for solids is $10^{-3}A_2$

If the excepted limit was chosen for a release from an Industrial Type 2 package then 10g ($A_2 \times 10^{-4}$ Bq/g $\div 10^{-3}A_2$) of soil could escape.

Using similar logic the loss from an IP-1 could be unlimited; therefore IP-1 will not be considered further.

If simulant powder density is taken as the density of loose dry sand, 1.8g/cm^3 then some 5 cm^3 of simulant would escape if 10g were released. Whilst no quantitative work has been performed to assess what the minimum visual detection level might be it would seem safe to think that 0.5g of simulant would be detected, particularly if the leak is concentrated at the area of damage and the package under test is not larger than a cube of 1m. Therefore current practice using powder simulant and visual detection would appear to be able to detect a leak of 1/10 that of the excepted package limits. See figure 1.

Type A packages are limited to contents not above the A_2 value (unless the contents are special form sources – which are not considered herein) and not related to the specific activity of the payload. They have to meet additional requirements as set out in paragraph 643 below;

643.The *containment system* shall retain its *radioactive contents* under a reduction of ambient pressure to 60 kPa.

Contents vary in form from high specific activity solutions for medical use (eg F18 orTc99) or sludges or particles (pond sludge or environmental samples) to irradiated components which may tend to have lower specific activity or have the activity concentrated in one area of the component. Consequently the loss of small volumes or mass may carry high activity. These variations are considered below for several typical Type A packages. Furthermore, those packages that carry liquid and gases are required to be subjected to a 9m impact test, which is beyond normal conditions of transport and reflects the accident scenario, this requirement somewhat contradicts the 'contents are safe by virtue of limited activity' argument.

Consider a vial of F18 in solution, the activity is limited to A_2 i.e. 6×10^{-1} TBq and this is contained in a aqueous solution of $5cm^3$. The specific activity is therefore 1.2×10^{11} Bq/g. and from TS-R-1 Table 5 the excepted package limits for liquids is $10^{-4}A_2$, which equates to 6×10^{-5} TBq.

Using a similar comparison as before then detection of 0.5×10^{-4}g is required. TC99 has a similar A_2 value and therefore a similar level of detection would be required. This equates to $5mm^3$ of liquid, which would form a disc of 5mm diameter on absorbent paper 0.25mm thick, see figure 2 .

This can be detected by seeking visual evidence of leakage using a tracer dye and paper. Vials can be vacuum leak tested before and after the testing. See Figure 3. In practice the seals on the vials in Type A medical packages are rarely disrupted mechanically, the glass vial will usually break first.

5 CASE STUDIES

Drums - These are difficult to apply a pressure differential to because they have thin wall lids and any pressure differential above approximately 20kPa may distort the lid and could affect seal integrity. A simulant tracer powder is used and experience has shown any transient leak of powder is discernable on the drop test plate post test and will show the extent of dust migration across the seal boundary.

It must be notes that reliance on the UN testing alone is not without its pitfalls - the payload must not differ from that tested by the UN test and for solids and liquids a transient leak is permissible, a transient leak is not compatible with 'no loss'. Practical experience whilst testing at Gravatom has shown that some UN approved drums for solid payloads do exhibit a transient leak but appear to seal afterwards the seal burp has occurred.

Cuboid Packages - experience of testing with a box type design for the transport of lead used both a pressure differential and test powder (the belt and braces approach). The box had been designed to withstand a pressure differential of 5psi – 34kPa and had a wide seal face. Because the payload was contaminated lead a dust tracer was also used simply because needed to verify that no transient leakage occurred in the impact and it would be beneficial to see how much the seal face distorted. In the event the box remained leaktight when soap bubble tested at 5 psi (34kPa) and the tracer showed migration across only half of the seal face. (See Figure 4)

IP-2 ISO Containers as approved under TS-R-1 para 627

The Low Level Waste Repository, near the village of Drigg in Cumbria, is the UK's only authorised Low Level Waste disposal facility and is operated under contract to the Nuclear Decommissioning Authority (NDA) by LLW Repository Ltd. LLW Repository Ltd operates a fleet of 9 x height driven design variants of their specially designed top opening IP-2 ISO Freight Container to transport and dispose of waste in the engineered vaults. The variation in containers height is mainly associated with minimising any residual voidage by allowing flexibility in the mass to volume ratio at the same time as satisfying the handling and transport restrictions.

All design variants are fabricated from weldable structural carbon steel of similar grades and strength to that used in commercial ISO freight containers. The external surfaces of the packages are coated with a paint system to provide corrosion resistance for 5 years of normal use. The internal surfaces and the base of the packages remain unpainted. The packages consist of a bolted lid arrangement with a lattice base and associated grout port on the lid and a vent port on the end wall to facilitate the waste encapsulation requirements of the LLW Repository.

Retention of contents within the LLW Repository's IP-2 ISO containers is provided by the totally sealed welded construction of the body and lid, by single or twin lid seals and gaskets are fixed to the associated grout and ventilation ports.

Integrity of the package containment system is ensured by visual inspection of joints and seals and by the leakage tests carried out on manufacture, This ensures that the container is leak tight on completion of manufacture, prior to the application of the paint finish. The manufacturing container body leak tightness test is a qualitative gas bubble test on the container body which enables individual leaks in welded joints, to be detected. The lid seal arrangement leaktightness tests (utilising twin seals) is an isolation pressure fall test of the lid seal interspace.

The level of leak tightness set as a pass criterion for the body leak test has been set at 1 x 10^{-1} bar cm^3 s^{-1} Standard Leak Rate (SLR) for any individual leak. This level of leak tightness, which is equivalent to a capillary leak at a welded sheet joint (length of capillary 2mm) of about 40 μm, is identified as an acceptable leakage rate which can be practicably achieved. See figure 6 for test photograph.

The leak tightness test specified for the lid closure seals is a pressure fall test on the seal interspace. The standard of leak tightness set for the complete seal is 1 bar cm^3 s^{-1} SLR; this is identified and widely accepted as an acceptable leakage rate for Normal Conditions of Transport Package designs. This is a factor of 10 less restrictive than the manufacturing leak tightness requirement for the body, but is the sum of all leakage around the complete perimeter of both the inner and outer seals. This level of leak tightness would also show that there are no significant defects in the seals and closure system.

Leak tightness of the container after loading is assured by the procedures that are to be followed on loading. The procedures advise of the requirements for a lid seal leak interspace tests and grout and vent port vacuum box leak tests if, damage to seals or seal faces is detected during the pre-loading checks or upon the containers reaching their scheduled maintenance frequency.

Type A pharmaceutical packages - Glass vials are used largely in the radio-pharmacies and are subject to a 9m drop test (in their packaging) since they normally contain liquids. Common practice has been to verify leak tightness prior and post test by pre filling them with dyed water then placing them in a vacuum chamber surrounded by absorbent white paper. Leakage would be evident by visual inspection. Any transient leakage of liquid during drop testing would normally show on absorbent white paper, see figure 2.

6 CONCLUSION

The current methods reported on and as used above clearly demonstrate that simple simulants visually observed and pressure tests are sufficiently sensitive to detect leaks of solids of1/10 the excepted limits and up to the excepted limit of liquids and demonstrate in a practical sense that no loss has occurred.

Figures

Figure 1 Comparison between 10g of test dust on the left and 1g on the right (the dust is uncompressed).

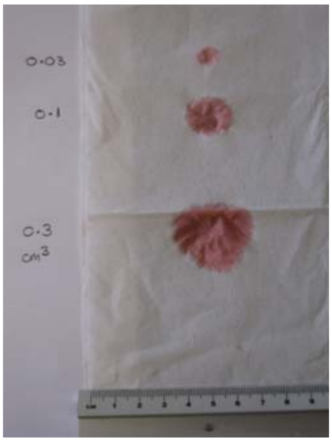

Figure 2 Comparison between different volumes (cm^3) of dyed water when applied to tissue paper.

Figure 3 Glass vial under vacuum testing.

Figure 4 An IP-2 post drop testing showing the migration of test dust across the seal boundary during a transient leak

Figure 5 Showing a Type A containment undergoing soap solution testing whilst pressurised internally to 1 bar.

Figure 6 showing an LLWR ISO freight container under test