The Development of ISO Freight Containers as IP-2 Packagings

M C Janicki and R A Vaughan

Croft Associates Limited, B2 North Culham Estate, Perimeter Road, Abingdon, Oxfordshire, England

INTRODUCTION

In 1987, British Nuclear Fuels plc (BNFL) as a result of a major programme of improvements in the method of disposal of LLW at the Drigg site in Cumbria, introduced the requirement for containerisation of all LLW to be consigned to Drigg for disposal. In the UK, Low Level Waste (LLW) is defined as waste having a radioactivity content of not more than 12 GBq/tonne beta/gamma and 4 GBq/tonne alpha. Such LLW does not normally require to be shielded during normal handling and transport.

Special freight containers were initially developed for the transport of this LLW to Drigg for disposal. However, the benefits offered by the use of freight containers for the transport, handling, and in some cases disposal, of large volume consignments of radioactive material were recognised and the use of special freight containers was subsequently adopted by the UK Nuclear Industry for the transport of LLW for both transport for Drigg disposal and for other transport operations.

The advantages perceived in using freight containers were that they could be manufactured economically and could be handled and transported using well developed systems. Freight containers are relatively low cost items, this being due primarily to the large numbers produced for dry cargo shipment of non-radioactive goods, and the well established and standardised manufacturing methods employed.

In 1987 when the use of freight containers for the transport and disposal of LLW was introduced, either the 1973 Revised Edition (As amended) or the 1985 Edition of the IAEA Transport Regulations could be used in the UK.

Under the 1973 Edition of the Transport Regulations, LLW was generally classified as Low Specific Activity (LSA) material which required packaging in an "industrial package". For this packaging standard the requirements were minimal and easily satisfied and did not include any testing or specified containment criteria. Some LLW of a higher activity level was classed as Low Level Solids (LLS), for which the packaging standard was a Strong Industrial Package. The requirements for a Strong Industrial Package included retention of contents following performance tests.

Under the 1985 Edition of the IAEA transport regulations, LLW is generally classified as Low Specific Activity (LSA) material or Surface Contaminated Objects (SCO). LSA material by virtue of its nature has a limited specific activity; for LSA-II the average specific activity for solid material must not exceed 10^{-4} A_2/g, and for LSA-III solids it must not exceed 2×10^{-3} A_2/g. For SCO, which is a solid object which is not itself radioactive but has radioactive material distributed on its surface, limits for fixed and non-fixed contamination are defined in the Regulations. Under "exclusive use" transport (which is always applicable for large freight containers), the packaging standard required is Industrial Package Type 2 (IP-2). The 1985 Edition of the IAEA Transport regulations specify a performance standard in terms of package testing and containment criteria that is generally more onerous than that specified in the earlier 1973 Edition of the IAEA Transport regulations for the same radioactive contents. The main requirement for an IP-2 package are that it shall protect against the loss or dispersal of the radioactive contents and loss of shielding under routine and normal conditions of transport.

The performance requirements for IP-2 freight containers, designed in accordance with the 1985 Edition of the Transport Regulations, are discussed in the following sections.

PERFORMANCE STANDARDS

In the 1985 Edition of the IAEA Transport Regulations, performance standards are specified for IP-2 packages which include design and test requirements. These requirements are intended to ensure that packages would not be significantly affected by conditions likely to be encountered in both routine transport, and normal conditions of transport including minor mishaps. For IP-2 packages, specific design requirements are stated (IAEA SS6 para 134):

- for a package (other than a tank or freight container)
- for a tank
- for a freight container

In the early stages of the development of the special freight containers, and prior to the introduction of the 1990 Amendment, there were interpretational difficulties with the 1985 Edition of the IAEA Transport Regulations. The main difficulty arose in the application of para 523 which is specific to freight containers. Para 523 stated, prior to the 1990 amendment, that freight containers may be used as IP-2 provided that they satisfy the requirements of ISO 1496/1-1978 without loss of shielding integrity greater than 20%. However, there was no specific containment criteria specified within para 523 or the ISO tests; the water spray test specified in the ISO tests (1496/1-1978) being a rainwater in-leakage test not a containment test. The omission of a containment criteria was clearly at variance with the intent and philosophy of the regulations for this standard of packaging. The Explanatory Material of the 1985 Edition of the IAEA Transport Regulations stated, prior to the 1990 Amendments, that release of contents considerations for IP-2 packages impose a containment function on the packaging for normal conditions of transport.

Due to the anomaly in the containment criteria of Paragraph 523, further unrelated concerns were raised as to the equivalence of the test conditions of the ISO tests (which are static tests) compared to the dynamic drop tests required for other industrial packages (excluding freight and tank containers).

This resulted in changes to the mechanical tests for freight containers being proposed, but these were not accepted in the IAEA review process which lead to the 1990 Amendment of the IAEA Transport Regulations. It was recognised that the static tests devised for freight containers are intended to simulate the dynamic loads occurring under normal conditions of transport. In undergoing the ISO tests, only elastic movement of the freight container structure is allowed. The ISO tests were considered to be more appropriate as representation of normal conditions of transport for freight containers, than the Type A tests. Also, freight containers designed in accordance with ISO 1496/1 have been proved, by the use of millions of units, to provide safe handling and transport under normal conditions of transport.

The 1990 Amendment to the IAEA Transport Regulations includes a containment criteria specific to para 523.

The following requirements for IP-2 freight containers as defined in paragraph 523 of the 1990 Amended issue of 1985 Edition of the IAEA Transport Regulations, are the basis for approval of IP-2 freight containers in the UK:

i) Packages must meet the general requirements for all packagings and packages.

ii) Packages must conform to the requirements prescribed in the International Standard ISO 1496/1-1978.

iii) When subject to the tests in ISO 1496/1-1978, packages must prevent:

   a) The loss or dispersal of the radioactive contents; and

   b) The loss of shielding integrity which would result in more than a 20% increase in the radiation level at any external surface of the package.

CONTAINMENT STANDARD

The containment standard specified for IP-2 packages (and for Type A packages) in the 1985 Edition of the IAEA Transport Regulations is that of 'no loss or dispersal' which has never been defined quantitatively in the regulations. The intent of the IAEA Transport Regulations in specifying a containment criteria for IP-2 packages, is to ensure that under normal conditions of transport the radioactive contents of the package cannot escape in sufficient quantities to create a radiological hazard.

In determining a practical and acceptable containment criteria for the IP-2 freight containers, due account was taken of the spirit of the IAEA Transport Regulations, guidance provided by the Advisory Material (Safety Series 37 - 1985 Edition), and the advice of the UK Competent Authority. The IAEA Transport Regulations provide for comparable levels of safety for radioactive materials of different radiotoxicities and different amounts, by relating the nature and amount of contents with graded packaging integrity requirements. The Explanatory Material (IAEA Safety Series No 7 paragraph E-519.1) states that "release of contents considerations for IP-2 packages impose a containment function on the packaging for normal conditions of transport". The Regulations also recognise that some simplification is possible with regard to containment standard for IP packagings, due to the nature of the LSA or SCO contents, as compared to the standard for Type A packagings that can contain an activity up to A_2 (not as special form radioactive material). The maximum activity of an IP package is limited by the package weight and allowable specific activity: for an ISO container carrying 20 tonne of LSA-III waste, the activity limit is 40×10^3 A_2.

For small quantities of radioactive material (ie $< A_2$) within the Type A limits, that in slightly larger quantities would require a Type B package, the containment standard for the containment vessel is commonly taken to be that specified for normal conditions of transport of Type B packages. A Type B package can contain in excess of an activity of A_2 (not as special form radioactive material). This containment standard is usually demonstrated by a gas leaktightness test at all the verification stages: that is Design, Fabrication, Assembly (pre-shipment) and Periodic.

In the UK, it is accepted by the Competent Authority (Department of Transport) that solid particulate material would not be expected to leak from a seal having a gas leaktightness of 5×10^{-4} bar cm^3 s^{-1} SLR (Vaughan 1987). The acceptance, of this level of gas leaktightness does not apply to specially produced fine powders, but in practice no such radioactive powders are produced.

For Type A packages, leaktightness of the containment vessel is usually demonstrated by tests performed at the Design, Fabrication and Periodic stages only. Design verification is carried out by leakage tests before and after testing of prototypes. Fabrication verification tests are carried out on manufacture to the same standard as Design verification. Periodic verification tests are carried out on maintenance after periods specified at the design stage and to the same standard as Design verification. Assembly verification of the containment system after loading the radioactive content is assured by operational checks and controls, and normally no actual leakage tests are performed.

In determining a containment standard for IP-2 packagings the general approach described above for Type A packages was considered to be appropriate, but it was recognised that some simplification from that adopted for Type A packaging was possible within the spirit of the Regulations.

QUALITY ASSURANCE

An important further consideration is that the 1985 Edition of the IAEA Transport Regulations emphasise the application of effective quality assurance and compliance assurance programmes to achieve safety of both the public and transport workers with respect to the transport of radioactive material.

In essence, the Regulatory requirements are directed at the shipper who is required to ensure that the package presented for transport will meet all the package design requirements, and specifically that the construction methods and materials used are in accordance with the design specification, and that all packagings built to an approved design are periodically inspected, repaired and maintained in good condition so that they continue to comply with all relevant requirements and specifications, even after repeated use.

The 1985 Edition of the IAEA Transport Regulations advise that the Quality Assurance programmes should be commensurate with the complexity of the packaging and its components, and the degree of hazard associated with the contents that may be carried: to this effect a system of grading packages or components of packages is defined, where the grade relates to the safety significance of the package or component.

Detailed guidance on the graded approach to QA is given in the Advisory Material IAEA Safety Series 37, 1985 Edition. This also provides advice as to the relationship between grading and package type. For IP-2 and IP-3 packagings, features affecting containment and shielding integrity are specified to be subject to GRADE 1. All other features should be subject to GRADE 2 except for those where there is a minimal effect on safety. It is noted that the grading required for containment for an IP-2 package is the same as that required for Type A and Type B packages.

To meet the requirements of the 1985 Edition of the IAEA Transport Regulations, and in particular the Quality Assurance requirements, verification of the containment standard is required at the stages of Design (Prototype Testing), Fabrication (Manufacture), Assembly (pre-shipment) and Periodically (normally annually in the UK but may be longer when justified) for reusable containers

These stages of verification are being used for the IP-2 freight containers designed to meet the 1985 Edition of the IAEA Transport Regulations. These measures are seen as being commensurate with the appropriate grading (ie GRADE 1).

DEMONSTRATION OF CONTAINMENT PERFORMANCE

In determining an appropriate containment standard, and a method of demonstrating this standard for IP-2 freight containers, a number of issues were considered. The Advisory Material IAEA Safety Series 37, 1985 Edition advises that it is difficult to suggest a single containment test method due to the wide range of packagings and contents. However, it is suggested that a qualitative approach which involves testing, may be employed for IP and Type A packages. A method suggested for solid contents in particular, involves the measurement of pressure rise or drop under some type of vacuum or pressure test. A simple bubble test is suggested for gaseous contents.

In determining a design basis for IP-2 freight containers, and recognising that a qualitative approach must have a quantitative pass/fail criteria described, it was seen as appropriate that the containment standard should be expressed as a gas leakage rate and that this should be verified at the appropriate stages. In determining an appropriate gas leakage rate the following factors were considered:

- what containment standard is appropriate for the form of the contents (ie LSA/SCO which, it is recognised, affords a degree of inherent safety)

- what is practically achievable for large volume containment vessels

- what test and test sensitivity is achievable in relation to practical manufacturing methods

- some relaxation from the Type A (normal conditions for Type B) containment test criteria

In arriving at a practically achievable test method and containment standard expressed as a leakage rate, an extensive test programme was carried out involving gas leakage testing and soap bubble testing of prototype freight containers. A mass spectrometer was used to detect helium gas leaking from a pressurised freight container. Leak detection was carried out on the container body and seals by pressuring the container with helium gas and 'sniffing' the external surfaces of the container body to detect leaks. By using this technique it was found that a test sensitivity of around 10^{-1} bar cm^3 s^{-1} SLR could be reproducibly achieved for individual leaks for freight containers designed to be nominally leaktight. It should be noted that a mass spectrometer of intrinsic sensitivity of around 10^{-10} to 10^{-11} bar cm^3 s^{-1} SLR was employed, but the resultant sensitivity of about 10^{-1} bar cm^3 s^{-1} SLR was due to conductances in pipe-work, partial pressure of helium gas, background levels and the use of a 'sniffer' probe.

The resulting test sensitivity reflected the level which was achievable within the manufacturing environment and by constraints imposed by the nature of the freight container design (ie a thin walled flexible structure). Improvements in the test sensitivity could possibly have been achieved by removing the freight containers to a laboratory controlled environment. However, any technique developed under these conditions would not necessarily have been reproducible or practical in carrying out verification of the containment standard during fabrication of large numbers of 'production' units.

This development work resulted in the conclusion that a containment standard of around 10^{-1} bar cm^3 s^{-1} SLR for individual leaks is achievable in the manufacturing environment. It was also concluded that this leaktightness could be readily reproduced, did not impose significant constraints on the design of IP-2 freight containers, and could, if required, be practically achieved and demonstrated at all stages of verification. Experience showed that all containment welds on the specially constructed freight containers could be readily leak tested to this standard. The development work provided useful information relating to the design of nominally leaktight freight containers. In particular, it was determined that it is necessary to ensure that all containment welds are accessible from outside the container and are visible.

As a further development, the sensitivity of a simple soap bubble test for measurement of leak rates on freight containers, was checked by a Helium leak detection technique. To achieve comparable results, both the Helium and Soap Bubble tests were carried out under the same conditions. It was found that for a particular Helium sensitivity, as achieved in the tests described above, the soap bubble technique offered a comparable sensitivity: this was also demonstrated when pressuring the containers with air. As the soap bubble technique using air as the test medium was easier and cheaper to perform, this technique was thereafter adopted for the leak testing of all production units of IP-2 freight containers.

A gas leakage rate of 10^{-1} bar cm^3 s^{-1} SLR is equivalent to a single capillary of 40 micrometre diameter and of length of 2mm (equivalent to the freight container wall thickness). In comparison, it is noted that a capillary of 12 micrometer diameter and of 2mm length has a gas leakage rate of 5×10^{-4} bar cm^3 s^{-1} SLR: this leakage rate being that accepted in the UK as providing absolute containment for fine powders in relatively free form.

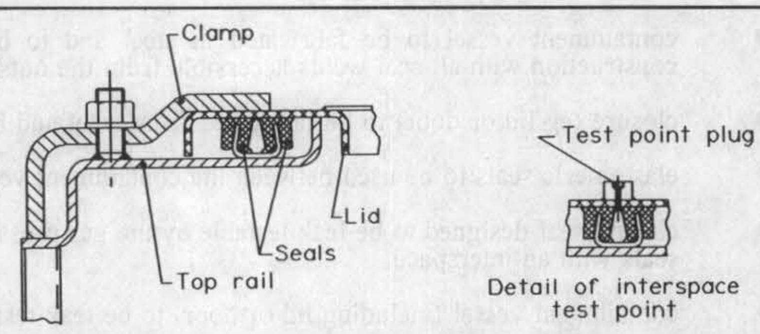
The smallness of the size of leakage path having a gas leakage rate of 10^{-1} bar cm^3 s^{-1} SLR was considered as unlikely to be the cause of powder leakage from freight containers because:

- there is virtually no pressure drive for leakage because the freight containers include filtered vents to ensure equalisation of internal pressure with ambient pressure. The filtered vents were included in the design because differential pressure changes were seen as undesirable, and difficult to design for, in a thin walled flexible structure.

- the radioactive material is not concentrated powders but powder mixed (diluted) with a spectrum of non-radioactive materials.

- the formation of aerosols containing radioactive material was considered to be unlikely due to the absence of significant mechanisms for making any radioactive powders airborne.

The closure systems of the IP-2 freight containers described above, are designed such that the containment standard of the closure seals can be verified independently of the container body. This is achieved by the use of a seal design that can be leak tested separately.



Cross Section of a Typical Seal Arrangement for a Top Opening Container

The arrangement currently in use consists of two elastomeric seals separated by an interspace. The resultant interspace volume can be pressurised and the pressure drop recorded over a period of time. This provides a measurement of the leakage rate of the seals. As this technique provides a measure of the gross leakage rate of the seals (ie not individual leaks), a relaxation of a factor of 10 was adopted resulting in an acceptance containment standard of 1 bar cm^3 s^{-1} SLR.

DESIGN FRAMEWORK

As a result of the above considerations, the design requirements listed below have been adopted in order to meet the performance requirements of the 1985 Edition of the IAEA Transport Regulations, for a freight container designated as an IP-2 packaging.

- O The freight container is to be designed to meet the design and test requirements of ISO 1496/1-1978.

- O The containment standard is to be demonstrated at the Design, Fabrication and Periodic stages by simple gas leak tests.

- Resealable closures are to be designed with double elastomeric seals which allow gas leak testing of both the containment vessel and the closure seals at all appropriate stages.

- For Design verification, the containment standard for the containment vessel and seals is to be tested before and after the ISO tests (ISO 1496/1 testing). The containment standard of the closure seals is also to be verified during the ISO racking tests.

- Assembly verification is to be provided by the combination of Fabrication verification and written procedures. If repair of the closure is required after manufacture, the double seals enable leak tests to be carried out to ensure that the repair is satisfactory.

- For reusable containers, the containment standard of the seals is to be verified annually and a detailed inspection carried out on the serviceability of the container. The container is to be maintained every five years, including leak testing of the containment vessel and verification that the container meets the requirements of the ISO tests.

- The containment standard is to be demonstrated at the appropriate stages by a gas leak test. The leak tightness levels currently adopted are:

Containment Vessel:	10^{-1} bar cm^3 s^1 SLR	(individual leaks detected)
Closure Seals:	1 bar cm^3 s^{-1} SLR	(gross leaks detected)

DESIGN SPECIFICATION

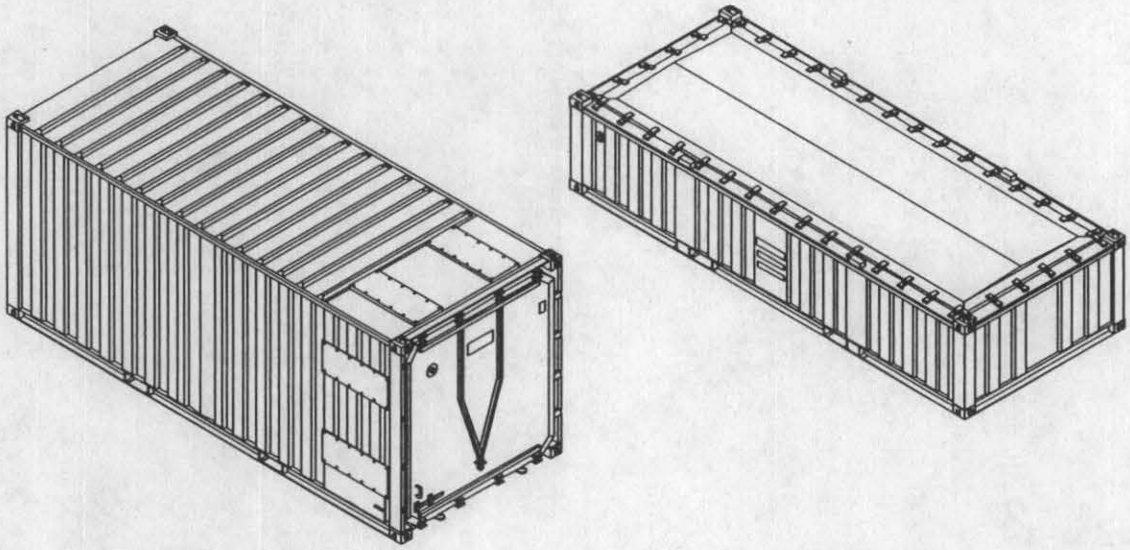
For a freight container the above considerations lead to the following generic design specification to enable the appropriate IP-2 regulatory requirements to be met:

- containment vessel to be fabricated in steel and to be of a continuously seal welded construction with all seal welds accessible from the outside.
- closure (eg lid or door) to be fabricated from steel and be of a seal welded construction.
- elastomeric seals to be used between the containment vessel and closure.
- closure seal designed to be leak testable by the gas pressure drop method by use of double seals with an interspace.
- containment vessel (including lid or door) to be leak testable by soap bubble method.
- container to be designed to meet the design and test requirements of ISO 1496/1-1978.
- tiedown arrangements to be provided for contents.
- filtered vents to be provided to ensure equalisation of changes in pressure due to changes in ambient temperature and pressure.

FREIGHT CONTAINER DESIGNS

A range of IP-2 freight container designs have been developed and manufactured, based on a range of standard sizes, in accordance with the above Design Specification.

The IP-2 freight container designs developed are of two generic types; top lid and single end door designs. The width of the freight containers of both types is fixed at 8 foot (2.4m). Freight containers with a single end door are manufactured in lengths of 10 foot, 20 foot and 40 foot (3m, 6m and 12m) and are of a height of 8 foot 6 inches (2.6m). Freight containers with a top lid are manufactured in lengths of 10 foot and 20 foot (3m and 6m) and are of heights of 4 foot and 8 foot 6 inches (1.2m and 2.6m).



Reusable Freight Container 6m x 2.4m x 2.6m **Top Opening Freight Container 6m x 2.4m x 1.2m**

CONCLUSION

Within the UK, freight containers are used in large numbers for the handling, transport, and disposal of LLW and to a lesser extent for other LSA or SCO materials. A design framework has been established for such freight containers to ensure that they meet the requirements of IP-2 packagings in accordance with the requirements of the 1985 Edition of the IAEA Transport Regulations.

The practicality of the interpretation of the Regulations embodied in this design framework has been proven by the design and manufacture of several different designs of IP-2 freight containers. The particular problem of providing a simple but adequate means of proving the adequacy of the containment of each freight container, at all the verification stages required by the Regulations, has been solved by establishing appropriate design criteria. The practicality of effecting this by testing has also been established on the large number of IP-2 freight containers built and tested.

REFERENCES

IAEA Safety Series No 6, Regulations for the Safe Transport of Radioactive Material, 1985 Edition, and 1985 Edition (As Amended 1990).

IAEA Safety Series No 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition (AS Amended).

IAEA Safety Series No 37, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition), Third Edition (As Amended 1990).

IAEA Safety Series No 7, Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition). Second Edition (As Amended 1990).

International Standard ISO 1496/1, Series 1 Freight Containers - Specification and Testing - Part 1: General Cargo Containers, 1978.

Private communication from UK Department of Transport to R A Vaughan, 21 December 1987.

CTR 92/30

PACKAGING TECHNOLOGY

Session 21:

SEAL/LEAKAGE-II

Chairman : L. Tanguy
Co-Chairman : H. Akiyama
Coordinator : T. Ohno