DESIGN AND TESTING OF NIREX 4m ILW BOX

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ABSTRACT

United Kingdom Nirex Limited (Nirex) has been established to develop and operate a deep underground repository for the disposal of the UK's intermediate level waste (ILW) and certain low level waste (LLW). Nirex has defined a limited number of standard containers for packaging the range of wastes arising from the UK. One standard container that has been defined is the 4m ILW box.

The 4m ILW box will be used to transport decommissioning ILW from sites of arising to a deep repository and for disposal of that waste in the repository. Consequently it must be designed to meet requirements for transport, handling and disposal.

The 4m ILW box is designed to meet International Atomic Energy Agency (IAEA), Safety Series 6 (SS6) requirements for an Industrial Packaging (IP-2) Freight Container. It is both a transport package and a disposal package and is suitable for waste materials that conform with the requirements for Low Specific Activity or Surface Contaminated Objects. The box is rated at 65t and has a nominal payload volume of $11m^3$.

A key feature of the design is the use of stainless steel for the structural and containment elements of the packaging. This approach has been adopted as the filled package may need to undergo interim storage pending the availability of a deep repository in the UK and the use of stainless steel will reduce the risk of deterioration of the packaging during this period.

INTRODUCTION

United Kingdom Nirex Limited (Nirex) has been established to develop and operate a deep underground repository for the disposal of the UK's intermediate level waste (ILW) and certain low level waste (LLW). Nirex has determined that major benefits will be accrued from definition of a limited number of standard containers for packaging the range of wastes arising in the UK. One standard container that has been defined is the 4m ILW box. It is provided with internal shielding and is designed to meet the requirements specified in IAEA SS6 for an IP-2 Freight Container.

The 4m ILW box is both a transport package and a disposal package, and is suitable for waste materials which can be classed as Low Specific Activity or Surface Contaminated Objects. The box is particularly suited for the packaging of decommissioning wastes, especially where the packager wishes to minimise the amount of size reduction required.

This paper describes work carried out by Nirex to design, manufacture and test a prototype 4m ILW box. A key feature of the design is the use of stainless steel for the structural and containment elements of the packaging and concrete for the shielding. It was also necessary to develop a special twistlock system that can accommodate the package weight of up to 65 tonnes.

CONTAINER SPECIFICATION

In the absence of Conditions for Acceptance, Nirex has developed a suite of Waste Package Specifications which describe the dimensions, key features and performance requirements for each of the standard waste packages. They include specific requirements for each package and formed the basis for the detailed container design specification for the 4m ILW box.

The box has been designed to meet the requirements for an IP-2 Freight Container specified in IAEA SS6 which have been incorporated into UK legislation. However, during the course of the work it was recognised that a new version of the transport regulations (ST-1) was in development and that IAEA SS6 would eventually be superseded. Hence, in developing the design specification account was taken of any additional requirements which were going to be included in the new version.

IAEA SS6 allows freight containers to be used as IP-2 packages provided that:

- requirements for Industrial Packages Type-1 are satisfied ;
- the container is designed to certain requirements of ISO 1496/1; and
- when subjected to tests prescribed in ISO 1496/1 prevent:

i. loss or dispersal of the radioactive contents; and
ii. loss of shielding which would result in more than 20% increase in surface radiation level.

The box was specified to be 4m long, top opening (no end doors), with a maximum gross weight of 65 tonnes. Concrete shielding of the contents was also required. These key features had been derived from previous work carried out by Nirex (Barlow *et al*, 1994) to study operating and handling of containers at waste producers' sites and disposal considerations. From studies of candidate waste streams suitable for disposal using the 4m ILW Box, it was expected that a shielding thickness between 100 to 300mm would cater for most applications, although a shield thickness of 50mm could be required at some stage. The test programme has concentrated on a box with 200mm shield thickness.

The specified maximum gross weight and length for the 4m ILW box do not fall within those recommended by ISO 1496/1 for standard freight containers. However, the box is consistent with the definition of a freight container given in IAEA SS6 and in ST-1, for such deviations are explicitly allowed.

In addition to the strength requirements of ISO 1496/1, the 4m ILW box was also required to withstand a repository operational stacking test, based on a six high stack of 65t boxes. The operational stacking test was based on the formula used to calculate the ISO 1496/1 stacking test for containers to be shipped by sea, which take account of the number of maximum gross weight containers in a stack and applies a 1.8 loading factor. The load also exceeds the maximum stacking loads required by ISO 1496/1.

CONTAINER DESIGN

A number of principles were applied to the design of the container:

- The skeletal frame (corner posts, top and bottom rails) of the container was designed to be able to withstand all the test forces applied to the container without assistance from the wall panels, lid or the concrete shielding.

- The wall panels were designed to withstand the side and end test forces (which simulate loads from the contents) without assistance from the concrete shield.

- The top lifting attachment points were designed to withstand ISO 1496/1 tests without exceeding the permissible stress defined according to the crane design code BS 2573.

- The base restraint attachment points were designed not to exceed yield when normal conditions of transport accelerations are applied.

- All containment welds were designed to be externally visible, to allow access for verification of containment by leakage testing.

- The lid seal system was designed for low compression force, the ability to accommodate tolerances in manufacture and to be compatible with proven verification methods for containment.

- The base was designed to provide a distribution of floor loading compatible with deep repository design concepts.

The 4m ILW box design is shown in Figure 1. The bottom side and end rails of the box are made from a 'U' channel section, as is the usual practice in freight container design. However, to maintain minimum shielding thickness without reducing the container cavity size, the channel is assembled with the open side facing into the container so that it fills with concrete when the shield is cast.

The floor is constructed from inverted 'L' sections which run between the side rails. These floor supports are fitted into the side rails, against which a 6mm thick floor skin is attached which completely covers the supports and end and side rails. Only the corner fittings protrude below the otherwise flat floor panel. On top of the floor supports there are straps running along the length of the container (90 degrees to the supports) to hold the supports upright. These members become redundant once the concrete floor shield has been cast.

Although it is not a formal requirement, the UK Competent Authority (DETR) was consulted during the project to seek interpretation of certain aspects of the regulations and endorsement of the approach being taken. In particular, the tie-down requirement was discussed. This was particularly relevant in the light of the new transport regulations ST-1, and the developing explanatory material in which it is expected that revised acceleration values may be defined.

The adopted accelerations and design criteria for the 4m ILW box tie- down components were as follows:

Design Stress	Accelerations (g)			Conditions of Transport
	Longitudinal	Lateral	Vertical	
Less than yield	±5	±2	±2	Normal
Permissible stress (BS 2573)	±2	±1	1 (upwards) 2 (downwards)	Routine
Fatigue requirements	±0.2	±0.25	±0.6	Routine

Shielding

The shielding has been designed to be cast directly into the container using a steel mould which is afterwards removed from the container. The container walls have angle ties welded on the inside to provide a key for the concrete. In addition to the ties, two sheets of reinforcing mesh are included in each shield. They are positioned 40mm below inner and outer surfaces of the concrete.

A step is cast at the top of the side and end shields. The step provides a surface to support thin concrete panels onto which the top concrete shield can be cast. Thus the casting of the top shield can be completed without support from the contents.

The shield when cast into the container will flow in between the floor members, into the side and end rails, into the corner posts and into the profiles of the side panels. The only voidage remaining in the container after packing is that within the wasteform and a small volume between the top shield and the stainless steel lid.

The void between the lid and the top shield is vented by provision of a filter fitted in the lid. The objective of the filtered vent is to prevent pressurisation of the container due to internally generated gases and due to temperature changes. The vent is fitted with a HEPA filter which removes particles down to 2 μm in size.

The Nirex 4m ILW box has been allocated Design Number 3852.

MANUFACTURE

Manufacture of the stainless steel box was completed using standard freight container manufacturing methods and techniques. The pre-formed sections were assembled around the eight corner fittings and construction welds made using the MIG process. The MIG process is favoured for these containers as they allow large amounts of weld to be laid quickly with minimum distortion.

TESTING

Following manufacture the prototype 4m ILW Box was subjected to a rigorous test programme to demonstrate:

- The design of freight container would withstand mechanical loads in accordance with ISO 1496/1 tests (normal conditions of transport tests).
- The design would prevent loss or dispersal when subjected to normal conditions of transport tests (IAEA Safety Series 6, Paragraph 523, b, i).
- The shielding effectiveness would not be reduced by more than 20% by normal conditions of transport test (IAEA Safety Series 6, Paragraph 523, b, ii).
- The container would withstand Nirex operational conditions.

The ability of the box to provide containment was demonstrated by conducting body and seal leakage tests. A combination of metrology checks and leakage tests was also used to verify that containment was maintained during and following mechanical tests to ISO 1496/1. The pressure drop technique and soap bubble method were used to confirm the leaktightness of the lid seal and body respectively.

The pass criteria for the leakage tests were set at 1 bar $cm^3 s^{-1}$ SLR for the lid seal and 0.1 bar $cm^3 s^{-1}$ SLR for the container body. These rates are considered to demonstrate containment against the criteria for IP-2 type packages and confirm 'no loss or dispersal' of contents during testing following an established methodology (Janicki and Hows, 1994).

Leakage tests carried out on the lid seal consisted of three pressure drop tests on each occasion. The tests were performed: before the load was applied, with load applied and after the load had been removed.

The ability of the shielding to withstand normal conditions of transport to the required standard was demonstrated by applying the ISO 1496/1 racking tests to the container 28 days after the concrete shield had been cast. The shield was fully constructed except that the top shield had been provided with an inspection port giving access into the container cavity.

A full listing of the ISO1496/1 tests which were performed and of the tests which were not performed, together with reasons why, is given in Annex 1.

Test Methods

An approved freight container test facility was used to test the container, but because of the high gross weight it was necessary to up-rate the test house so that the required loads could be applied. It was also necessary to produce a special testing frame to allow the non-standard length container to be accommodated and loaded within the facility. The test frame also included features for applying the restraint test loads.

Floor loadings, which can be as much as twice the container payload, have to be applied during some of the tests. These are normally applied by loading the container with concrete or steel weights. The prototype 4m ILW box could not be loaded in this manner as the number of the weights required to achieve the load could not be accommodated within the test facility. Therefore, to achieve the required load, a set of hydraulic cylinders were mounted centrally over the box aperture and used to apply a supplementary load to the conventionally placed weights.

Normal practice is to apply the side and end wall loads either by laying the container on its side and filling it with weights or by using an air bag inside the container. Neither method was suitable for the 4m box because of the magnitude of the required test load. The method adopted was to construct a loading frame, fitted with hydraulic cylinders, which could apply a uniform load to the wall by use of a spreader plate acting against sand bags placed against the appropriate wall.

Pass Criteria and Test Results

As noted previously the pass criteria for the leakage tests were set at 0.1 bar cm^3 s^{-1} SLR for the container body and 1 bar cm^3 s^{-1} SLR for the lid seal. All the leakage tests performed were passed by a good margin.

During load testing, ISO 1496/1 allows elastic deformation and a small amount of 'permanent set'. The main criterion used to judge whether the permanent set is acceptable or not is that it should not affect the operation and handling of the container. Permanent set needs to be considered from two view points: container dimension /geometry and structural strength /stability. For example, if the side wall had a permanent set which protruded beyond the top and bottom rail this would be considered a failure as the container would not fit within an array of containers, similarly if the structural frame became distorted so the container could not be locked down to a twistlock system or to a lifting frame, this would also be deemed a failure. Damage which affects the container structural strength /stability includes: on-set of buckling of the corner posts, distortion of the corner fittings and compression damage to the side panels.

The container design was assessed, the manufacture monitored, and testing witnessed by Lloyd's Register under the Container Certification Scheme. All of the tests were passed, and the container was issued with a CSC certificate under the International Convention for Safe Containers scheme.

CONCLUSIONS

A 4m ILW box, as defined in the Nirex Waste Package Specifications, has been designed, manufactured and successfully tested to meet the requirements for an IP-2 freight container to ISO 1496/1. The work has confirmed the acceptability of modified testing methods for freight container with a gross mass of 65 tonne.

The 4m ILW box project has demonstrated that the well tried and tested ISO freight packaging and handling systems can be adapted and developed to fulfil the exacting requirements of the nuclear industry for the packaging, transport and disposal of intermediate level waste.

REFERENCES

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Annex 1. ISO1496/1 Test Schedule

Tests Performed

- Stacking test, including Nirex operational stacking test
- Top lift
- Restraint (longitudinal)
- End loading
- Side loading
- Roof load
- Rigidity transverse
- Rigidity longitudinal
- Weatherproofness
- Concrete shield tests

It is a requirement of ISO 1496/1 that the container floor be loaded during a number of the above tests, and loads varying between 1.8 or 2 times the container payload were used. The payload for the 4m ILW box is 61 tonnes, when the concrete shielding is included as part of the payload.

Tests not Performed

The following tests, which complete the full list of tests specified by ISO 1496/1, were not performed because the features which they test were not included in the design of the 4m ILW box.

- Bottom lift - bottom lift apertures are not provided in the corner fittings;
- Fork lift pockets - fork lift pockets are not provided in the container;
- Wheel loads - loading vehicles cannot drive into the container;
- Grappler lift - grappler attachments are not provided on the container.

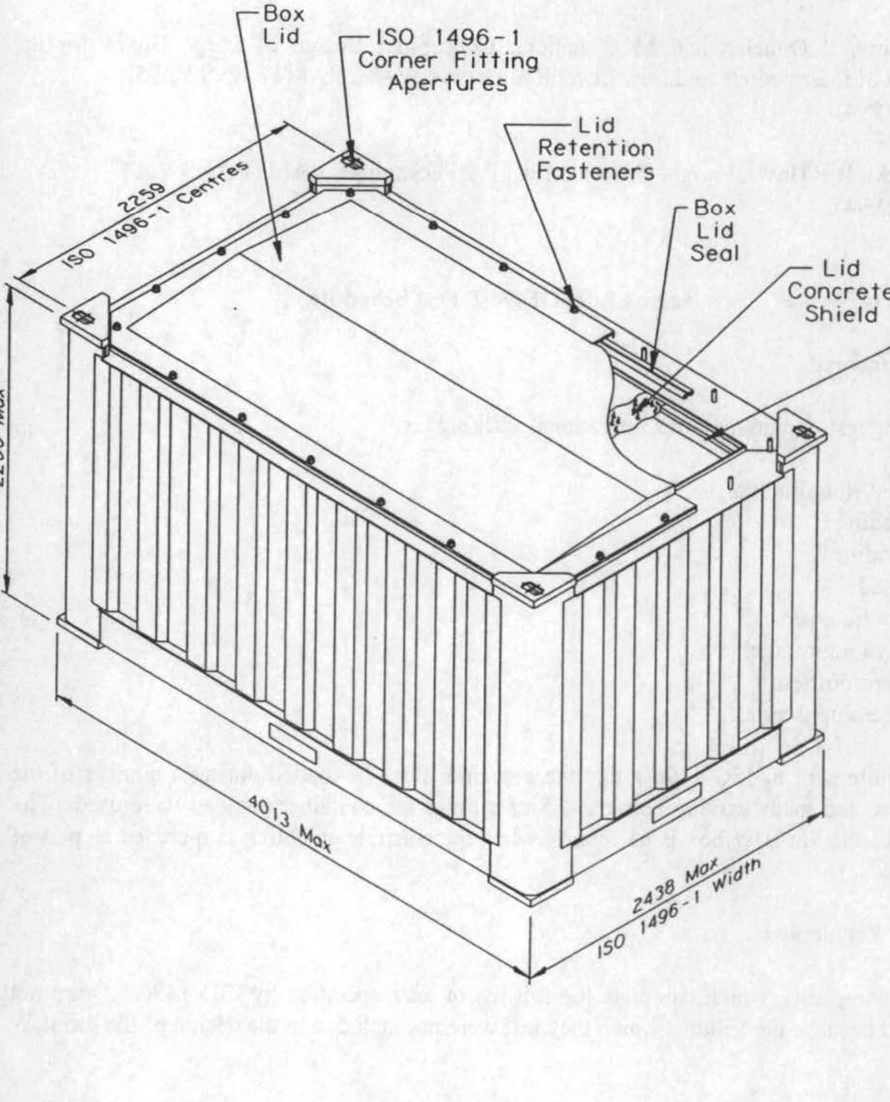

Figure 1 : 4m ILW BOX DESIGN No. 3852