An Overview of the Development of IP-2 ISO Freight Containers in the UK

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Abstract

This paper records the establishment within the UK of the use of IP-2 packages for Low Level Waste (LLW) based on the design features and established ISO standards for ISO Freight Containers for which Croft was the prime mover. The first designs developed were required for the shipment of LLW to BNFL, Sellafield and Drigg and for the emplacement of waste in the Drigg LLW vaults. These designs were established by Croft Associates Ltd (Croft) and adopted by a UK industry wide group called "The ISO Procurement Club" which co-ordinated the technical and commercial requirements of the principal producers of LLW in the UK. Croft managed The ISO Procurement Club, including managing the manufacture, storage and distribution of the first 2,000 IP-2 ISO Freight Containers built in the UK. Croft carried out all the design work, developed design approaches (especially leak testable seals and lid closure systems), and established standards which have since been adopted in a DfT design guide. Croft was also involved in the development of the special provisions for Freight Containers that have been included in the IAEA TS-R-1 Regulations for the Safe Transport of Radioactive Materials. Since the early designs, there has been a requirement for a number of different sizes of IP-2 ISO Freight Containers and a number of special designs for large heavy items requiring special internal tie-down arrangements. Croft has designed most of the IP-2 ISO Freight Containers used and currently in use in the UK for the transport and storage of LLW.

The paper details the key requirements for the design of IP-2 ISO Freight Containers, summarises the designs established since their initial use over 20 years ago and the designs currently in use in the UK, and gives outline details of shielded IP-2 ISO Freight Containers proposed for emplacement in the UK radioactive waste repository.

Background

Since the early days of the UK nuclear industry, Low Level Radioactive Waste (LLW) has been disposed of in waste disposal vaults at the Low Level Waste Repository located near Drigg in Cumbria. This facility is located near BNFL (now Sellafield Ltd) and accepts most of the LLW in the UK which arises from the reprocessing of irradiated nuclear fuel from power reactors and the operation and decommissioning of nuclear power stations and other nuclear facilities. The Low Level Waste Repository used to be managed by BNFL but now comes under the ownership of the NDA and is managed on their behalf by LLW Repository Ltd.

Until 1988, the LLW was "tumble tipped" into special vaults consisting of a shallow trench lined with clay; after these trenches were full, they were covered in clay to prevent ingress of rainwater.

In 1987 BNFL decided to improve the efficiency of the disposal area available and to improve the long term environmental safety associated with the trenches. This was achieved by the introduction of a number of measures which included: using concrete lined vaults; packaging waste in primary disposal containers, and pre-sorting of waste to reduce waste volumes.

The packaging (primary disposal containers) proposed by BNFL originally were 200 litre drums in 12 pack stillages (3x2x2 high array) and steel boxes with volumes of 4.5m^3 and 9m^3. As an alternative Croft Associates proposed the use of special IP-2 ISO Freight Containers of volume 17 m^3 and 37 m^3 - these being the Half Height IP-2 ISO Freight Container (2.4m wide, 6m long and 1.2m high) and the Full Height IP-2 ISO Freight Container (2.4m wide, 6m long and 2.6m high). These special IP-2 ISO Freight Containers were manufactured using conventional freight container technologies, but modified to provide improved containment (not required in the conventional freight container industry), to meet the requirements for an IP-2 package. Croft had outlined the designs for these containers and cost estimates had shown that there would be substantial savings by using these special IP-2 ISO Freight Containers instead of using the much smaller containers proposed by BNFL.

The CEGB (now mainly reformed as British Energy and Magnox), who were major shippers of LLW from their power stations to Low Level Waste Repository, were very interested in Croft's proposals. Principally, the approach proposed by Croft offered significant cost savings in LLW disposal, and Croft and the CEGB worked together to get acceptance of the Croft special IP-2 ISO Freight Containers by BNFL for disposal of LLW at the Low Level Waste Repository near Drigg.

Croft gained acceptance from the UK Competent Authority of the design principles and the approaches proposed to demonstrate compliance with the IAEA Transport Regulations relevant at that time: these are further explained later in this paper.

BNFL issued, after due consideration, an approval for use of these special IP-2 ISO Freight Containers by the CEGB and other waste producers, and in due course the Croft Half Height and Full Height IP-2 ISO Freight Containers were adopted as the *de facto* standard containers for disposal of LLW, including BNFL's own LLW, at the Low Level Waste Repository at Drigg. BNFL went on to improve the efficiency of waste disposal by the introduction of supercompaction for some of the wastes (i.e. compactable wastes) designated for disposal in the Half Height IP-2 ISO Freight Containers.

At the end of 1987, Croft had designed, tested and manufactured the first batches of 100 Full Height IP-2 ISO Freight Containers (design # 2894) and 100 Half Height IP-2 ISO Freight Containers (design # 2895) for use by the principle waste producers in the UK nuclear industry. These were supplied to the UK nuclear industry in early 1988 – this was effected through a UK nuclear industry group which became known as "The ISO Procurement Club" which is further explained later in this paper.

Transport Regulations for IP-2 ISO Freight Containers

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. For LLW of a higher activity level classified as Low Level Solids (LLS) the packaging standard was a Strong Industrial Package for which retention of contents following performance tests was required.

In the 1985 Edition of the IAEA Transport Regulations, a performance standard was introduced for LLW classified as Low Specific Activity (LSA) material or as Surface Contaminated Objects (SCO); the requirement added was that there be no loss or dispersal of the radioactive contents and no loss of shielding under routine and normal conditions of transport.

The 1990 Amendment to the IAEA Transport Regulations clarified the requirements for IP-2 ISO Freight Containers (in para 523) as below – these are the same as specified in the current IAEA Transport Regulations (Ref 1).

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 (Ref 2).
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.

Details of the development of the regulatory situation are given in more detail in a PATRAM 1992 paper by Janicki and Vaughan (Ref 3).

The objective of the containment standard of "no loss or dispersal", which has never been defined quantitatively in the regulations, 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.

The containment standard adopted for IP-2 ISO Freight Containers in the UK following a test program and consultations with the Competent Authority (DoT), is that containment be verified at the appropriate stages by a gas leak test with a pass criteria as follows.

Containment body	0.1 bar cm^3 s^1 SLR (Ref 4) (individual leaks detected)
Closure Seals	1.0 bar cm^3 s^1 SLR (Ref 4) (gross leaks detected)

The UK Competent Authority issued a guide to the approval of IP-2 ISO Freight Containers as Type IP-2 and Type IP-3 Packages in 1999 which was reissued as the current document in 2005 (Ref 5).

Design Parameters for IP-2 ISO Freight Containers

Croft developed the following generic design specification for IP-2 ISO Freight Containers; this covers the key requirements necessary to meet the regulatory requirements and interpretations developed in consultation with the Competent Authority and the UK nuclear industry.

- The container be designed to meet the design and test requirements of ISO 1496/1-1978.
- The containment fabricated in steel and be of a continuously seal welded construction with externally accessible seal welds.
- For end opening containers, the closure be in the form of a single door as the usual double doors in ISO Freight Containers cannot not be shown to provide adequate containment of particulate contents.
- For top opening containers, the closure be in the form of a removable lid.
- The closure (eg lid or door) be fabricated from steel and be of a continuous seal welded construction.

- Elastomeric seals be used in the containment vessel closure system.
- The closure seal be designed to be leak testable: such as use of double seals with an interspace and leak testing by the gas pressure drop method.
- The containment vessel (including lid or door) be leak testable: such as by soap bubble method.
- For design verification, the containment standard for the containment vessel and seals be tested before and after the ISO tests (ISO 1496/1 testing). The containment standard of the closure seals should be verified during the ISO racking tests.
- For reusable containers, the containment standard of the seals be verified annually.
- Tie-down arrangements be provided for the contents.
- HEPA filtered vents be provided when necessary to ensure equalisation of changes in pressure due to changes in ambient temperature and pressure.

The ISO Procurement Club

The ISO Procurement Club (The Club) was a UK nuclear industry wide group formed specifically to co-ordinate the needs of the UK nuclear industry for IP-2 ISO Freight Containers for LLW - The Club coordinated the commercial requirements of the principal producers of LLW in the UK. The first meeting of The Club was held in Bankside Power Station (now the Tate Modern) on Christmas Eve 1987 and resulted in The Club dividing up the 200 containers which Croft had manufactured, between its members. At this meeting an informal agreement was made for future operation of The Club. The Club held monthly meetings for five years with rotating chairmanship by Club members with Croft providing the secretariat. At The Club's monthly meetings, decisions were taken on technical and commercial requirements: this included managing the development of new designs and determining optimal procurement by bulk purchase for the containers through Croft. New designs were introduced which were based on the Croft original designs with only minor design improvements as agreed by Croft. The design ownership was agreed to be Croft and all members of The Club – this was deemed to be equitable as all members contributed to the cost of new design work and Croft contributed the original designs. In 1995, by which time BNFL had developed its supercompaction plant at Sellafield and had further developed its methodology for efficient use of Drigg, BNFL declared that they would become the supplier to The Club members and it was agreed that The Club was no longer needed and it ceased its activities.

During the operation of The Club, Croft had managed all design changes and managed the manufacture, storage and distribution of over 2,000 IP-2 ISO Freight Containers, all of which were built in the UK. After dissolution of The Club, Croft continued to provide design services in the development of IP-2 ISO Freight Containers to BNFL and continues to provide design services for new design IP-2 ISO Freight Containers to LLWR.

IP-2 ISO Freight Container designs

Early Croft designs

The early designs of special IP-2 ISO Freight Containers developed by Croft (Design # 2894, # 2895, # 2896 and # 2899) are shown in Figures 1, 2, 3 and 4 respectively. In producing these designs, Croft developed novel container body designs and novel closure and sealing systems which have been used with little variation for all the IP-2 ISO Freight Containers developed by Croft – which is nearly all the IP-2 ISO Freight Containers used and in use in the UK for the transport and disposal of LLW.

Figure 1. IP-2 ISO Freight Container Design # 2894	Figure 2. IP-2 ISO Freight Container Design # 2895
	
• 2.4 wide, 6m long, 2.6m high IP-2 unsealed ISO Freight Container. • Designed as a reusable container to carry IP-2 drums and other IP-2 contents which at that time were deemed to provide some of the containment. • Also available as Design # 2912 – this being standard IP-2 ISO Freight Container refurbished and modified	• 2.4 wide, 6m long, 1.2m high IP-2 sealed ISO Freight Container • Designed as an IP-2 single use container to carry uncontained materials such as rubble, immobilized sludges, large contaminated items, decommissioning wastes. • Design for direct disposal at Drigg.

Figure 3. IP-2 ISO Freight Container Design # 2896	Figure 4. IP-2 ISO Freight Container Design # 2899 (shown with lid off)
	
• 2.4 wide, 6m long, 2.6m high IP-2 sealed IP-2 ISO Freight Container • Designed as a reusable IP-2 container to carry unqualified drums and other contents not packaged as IP-2.	• 2.4 wide, 6m long, 2.6m high IP-2 sealed IP-2 ISO Freight Container • Designed where top loading is essential to carry non-IP-2 drums, wrapped items, etc. • Used also as an emergency response container into

• Can be fitted with internal loading rails and tie-down system. • Tare weight 6 tonne, loaded weight 25 tonne.	which contaminated wastes from an incident could be placed.. • Tare weight 4 tonne, loaded weight 25 tonne.

Designs under The ISO Procurement Club

The IP-2 ISO Freight Containers supplied to The Club were initially the Croft original Designs # 2894 and # 2895. The experience of manufacturing and using the first 200 containers resulted in the need for minor design changes. The existing Croft designs were taken as the basis of new designs which incorporated these minor changes: these were given new design numbers (# 2031 and # 2032) – these are shown in Figures 5 and 6.

BNFL and LLWR (Drigg) Designs

When BNFL took over the procurement of IP-2 ISO Freight Containers previously supplied by Croft and The Club, two new containers Designs # 2910 and # 2947 (shown in Figures 7 and 8) were designed by Croft for BNFL: Design # 2910 and Design # 2947 were designed to minimize the external void space when close stacked and Design # 2947 incorporated an over lid to shed rainwater.

In 2006 Croft designed the Bolted End Door IP-2 ISO Freight Container shown in Figure 9 - for BNFL – this was required for use in countries having very low environmental temperatures and for closing with simple tools rather than powered hydraulic pumps as used for the similar Design # 2896.

In 2010 Croft designed the TC-02 IP-2 ISO Freight Container shown in Figure 10 for LLWR Ltd - this container is designed for multiple use rather than transport and disposal. The container is designed specifically to facilitate internal decontamination and is provided with features for the internal restraint of LLW packaged in a range of boxes mounted on pallets/stillages.

Figure 5. IP-2 ISO Freight Container Design # 2031	Figure 6. IP-2 ISO Freight Container Design # 2032
	
• 2.4 wide, 6m long, 2.6m high IP-2 unsealed IP-2 ISO Freight Container • Designed as a reusable container to carry IP-2 drums and other IP-2 contents which were deemed to provide some of the containment. • Tare weight 3 tonne, loaded weight 25 tonne.	• 2.4 wide, 6m long, 1.2m high IP-2 sealed IP-2 ISO Freight Container • Designed as a single use container to carry non-IP-2 wastes such as rubble, immobilized sludges, large contaminated items, decommissioning wastes. • Designed for direct disposal at Drigg. • Can be grouted.

	• Tare weight 3 tonne, loaded weight 35 tonne.

Figure 7. IP-2 ISO Freight Container Design # 2910	Figure 8. IP-2 ISO Freight Container Design # 2947
	
• 2.4 wide, 6m long, 1.2m high IP-2 sealed IP-2 ISO Freight Container • Designed as a single use container to carry drums compacted into pucks and to have minimum external void volume within the main external dimensions. • Designed to be grouted. • Tare weight 3 tonne, loaded weight 35 tonne.	• 2.5m wide (pallet wide), 6m long, 1.2m high IP-2 sealed IP-2 ISO Freight Container • Designed as a single use container primarily for use by BNFL to carry 1m³ supercompacted boxes • Tare weight 3 tonne, loaded weight 35 tonne.

Figure 9. IP-2 Fissile ISO Freight Container – Bolted end door	Figure 10. IP-2 ISO Freight Container Design TC-02

	
• 2.4 wide, 6m long, 2.6m high IP-2 sealed ISO Freight Container having a single bolted end door. • Designed specifically for use in countries having very low environmental temperatures and for closing with simple tools rather than powered hydraulic pumps as used for the similar Design #	• 2.4 wide, 6m long, 1.2m high IP-2 sealed ISO Freight Container • Designed for LLWR Ltd for multiple use rather than transport and disposal. Internal design specifically to facilitate decontamination and restraint of LLW packaged in a range of boxes mounted on

Figure 11. Type B Contents Special Arrangement ISO Freight Container Design #2913

	• 2.4 wide, 6m long, 2.6m high sealed ISO Freight Container. • Designed as a reusable container to carry GRP boxes and drums containing Type B contents under Special Arrangement. • Approved contents principally drums and wrapped boxes containing Pu contaminated items. • Fitted with thermal insulation, internal loading rails and tie-down system. • Tare weight 5 tonne, loaded weight 25 tonne.
Type B Contents Special Arrangement, ISO Freight Container Design #2909 (similar to but much larger than 2913 - not built)	• 2.85 wide, 6m long, 3.6m high sealed ISO Freight Container. • Designed as a reusable container to carry large GRP boxes containing Type B contents under Special Arrangement. • Never built but is a useful concept should a container be needed to ship very large objects, or to

Designs for Type B contents under Special Arrangement

Croft developed two IP-2 ISO Freight Containers specifically for the shipment of items contaminated with Type B quantities of Plutonium. Design # 2913 shown in Figure 11 was used under Special Arrangement in the UK of such items in large GRP boxes and drums. A much larger container Design # 2909 was also designed for very large Pu contaminated items and, although fully developed, was never built (the oversize items were size reduced for shipment in smaller Type B containers).

For the Special Arrangement approval, design features were added to meet, as far as practicable, all the requirements of the Type B regulations; this included insulation on the inner surfaces of the container, robust tie-down of contents and testing to show that the package could meet the Normal Conditions of Transport criteria by drop testing a loaded package on its base and on its side. Safety equivalent to that for a Type B package was shown by addition of shipping controls and a detailed risk assessment of a restricted route and shipment with special controls.

Designs for ILW

The ILW designs shown in Figures 12 and 13 were developed by Croft for Nirex (now the Radioactive Waste Management Division (RWMD) of the Nuclear Decommissioning Authority (NDA)) and UKAEA's Winfrith site (which is now known as Research Sites Restoration Limited (RSRL)) which is owned by the NDA and operated on their behalf by UKAEA Ltd (who are now owned by Babcock International Group PLC). The two designs are intended for the transport and disposal of ILW solid wastes to the NDA radioactive waste repository These designs are based on ISO freight container standards, have thick stainless steel walls and are designed for long term storage before shipment. The designs are fully tested and available. These containers are IP-2 packages and are intended for ILW that meets the requirements of LSA or SCO materials but need additional shielding to meet the dose rate requirements of the IAEA Transport Regulations. Additional shielding is provided by concrete being cast into the internal void space to create internal concrete walls which can be cast in a range of thicknesses typically from 100mm to 300mm.The external stainless steel walls provide the containment function and are constructed in a similar manner as other IP-2 ISO Freight Container constructions. The Nirex container is designed for gross weight of 65 tonne and the UKAEA container for up to 40 tonnes gross weight.

Figure 12. 4m Box (Nirex (RWMD NDA) 4m Box)	Figure 13. 2m Box (UKAEA (RSRL) 2m Box)

	
• 2.4 wide, 4m long, 2.6m high sealed IP-2 ISO Freight Container lined with 100mm to 300mm concrete to provide shielding. • Approved for use by Nirex for disposal of ILW in the UK Repository. • Designed as a single use package within which the contents would normally be grouted.	• 2.4 wide, 2m long, 2.2m high sealed IP-2 ISO Freight Container lined with 100mm to 300mm concrete to provide shielding. • Drop tested to IP-2 requirements. • In process of approval by RWMD, NDA for use for disposal of ILW in the UK Repository. • Designed as a single use package within which the

Croft is in the process of developing a 2m Cube Cast Iron Box shown in Figure 14 – this is seen as the most appropriate design for certain ILW wastes that have to be packaged before the UK Repository is open. The package is designed as an IP-2 ISO Freight Container cast from nodular cast iron which provides shielding and therefore the package can be stored in a simple unshielded store pending shipment to the UK Repository. The procedure for seeking authorization for acceptance for this type of package for the UK Repository is in process.

Figure 14. 2m Cube Cast Iron Box

	• 2m wide, 2m long, 2m high sealed IP-2 ISO Freight Container of various thicknesses of nodular cast iron from 50 to 145mm which provides shielding. • Outline design approval of this type of package is in the process of review by RWMD, NDA for use for disposal of ILW in the UK Repository. • Designed as a single use package but could be unloaded if required. • Grouting of contents would not normally be required. • Tare weight 8 tonne (for 50 mm wall thickness), loaded weight 40 tonne.

Emplacement of IP-2 ISO Freight Containers in the Drigg vaults

Since the first introduction in 1988 of the use of IP-2 ISO Freight Containers for the shipment and disposal of LLW in the UK, about 10,000 IP-2 ISO Freight Containers have been emplaced in the vaults at Drigg. Figure 15 shows Vault 8 at Drigg in 2009. The majority of the containers that can be seen in the vault are half height IP-2 ISO Freight Containers (Design #s 2895, 2032, 2910 and 2947).

Figure 15. LLWR waste burial site at Drigg

Conclusion

The use of IP-2 ISO Freight Containers in the UK has developed over the last 23 years from a concept that overthrew established methods, to be the de facto standard design style for packages to transport and dispose of LLW. Although there have been a number of design changes to meet improvements in waste emplacement, the key design approaches developed by Croft, especially the design of the container bodies to provide a leak tight vessel and the leak testable seals to provide containment of the closure, have not changed.

Since their inception, the use of IP-2 ISO Freight Containers has been extended through special designs to cover the shipment of large heavy contaminated objects including the shipment of plutonium contaminated wastes under Special Arrangement.

Recent designs have extended the design principles used in the IP-2 ISO Freight Containers to ILW containers of weight up to 60 tonne, with shielding being provided by concrete or malleable cast iron. These shielded containers also offer a viable alternative to the on-site storage of waste that requires on-site shielded facilities which can be costly to build, operate and maintain.

The experience of producing all the designs described in this paper, has shown that it is practical to produce designs that meet the regulatory requirements, including features such as testable seals that provide evidence of quality compliance, without introducing excessive cost.

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AWE Aldermaston	DoT, RMTD	UKAEA
BNFL	LLWR (Drigg)	
CEGB, Barnwood	Nirex, later RWMD, NDA	

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