New Container Development for the International Market – 15656

Dr. Wolfgang Steinwarz
Siempelkamp Nukleartechnik GmbH, Siempelkampstrasse 45, 47803 Krefeld, Germany
wolfgang.steinwarz@siempelkamp.com

ABSTRACT

Designs of casks and containers for the disposal of radioactive waste have to meet safety requirements for transport and storage. Since nuclear law is a national issue, the legal specifications often differ significantly. To improve the flexibility of a given basic design, the development of a set of generic design elements and the application of favorable material characteristics are of major importance.

As an example for the international approach the design development for an IP-2 container for radioactive non-fuel waste made of Ductile Cast Iron (DCI) for the UK market in the frame of the specific national waste disposal concept is described. The results of drop tests performed during the licensing procedure and of parametric analysis work regarding a wide spectrum of accidental scenarios and impacts show the excellent behavior of the container concept and confirm the related favorable manufacturing procedures. Furthermore, the development work provided a significant set of proposals for the future detailed work.

INTRODUCTION

There is a wide range of containers of different types available for the safe handling of radioactive wastes during transport and storage with varying levels of shielding effectiveness as well as different shapes and sizes. Depending on the requirements, various materials are used – e. g. steel/sheet steel, concrete or cast iron.

A number of laws form the framework conditions for container production: traffic law, the Atomic Energy Act, the Radiation Protection Ordinance and the storage conditions of the interim and final storage facilities. Each has their individual requirements. Therefore, the containers must ensure the required radiation shielding and tightness, e. g. depending on the radioactive inventory. They also have to satisfy certain integrity criteria taking into account normal and accident conditions of transport.

This all gives rise to special qualification features for the material and the related process to manufacture a widely flexible product covering the spectrum of criteria in one generic solution.

THE MATERIAL AND THE CASTING PROCESS

After a long-term material optimization process over decades and a production record of more than 11,000 nuclear licensed and successfully used casks and containers mainly for the German market, it can be stated that DCI is a comprehensive solution.

The special properties of the material lie in its ferritic microstructure with embedded, ball-shaped graphite particles. This structure favors ductile and therefore cushioning behavior with respect to external influences (e. g. crack inhibition). The feature which is responsible for this in particular is the relatively high carbon content at around 3.6 % and a sophisticated and detailed chemical analysis with special trace elements for the casting process. The suitability of the material has been proven over many decades in a series of qualified tests and is well documented with respect to its general properties like tensile strength, elongation and fracture toughness and more importantly, the latter with respect to dynamic conditions [1].

In addition, the technical casting process provides a monolithic container structure under the motto "everything from a single source" without seams (i. e. welds) with a highly flexible design concept covering generally all types of container qualifications (IP-2, A, B).

BASIC ISSUES FOR FLEXIBLE CONTAINER DESIGNS

Using this basis a review of international atomic regulations including major national disposal programs and concepts has been performed. The results led to a set of new generic design elements and marked the high importance of the material properties for meeting the enhanced safety approaches during the last years and the expected developments within the future safety regulations.

In order to choose the most appropriate Ductile Cast Iron Container (DCIC) variant – cylindrical or cuboidal, see Fig. 1 - for a given waste the following criteria have to be assessed [2]:

- mechanical strength according to storage and transport conditions (containment and stacking requirements, accidental impacts),
- intermediate and long-term material influences (resistance to degradation),
- container utilization and cost,
- radiation shielding (activity and anticipated dose rate),
- waste volume,
- waste physical form,
- conditioning requirements and
- proposed waste loading method. This may include the use of loading baskets or drums for the cylindrical version.

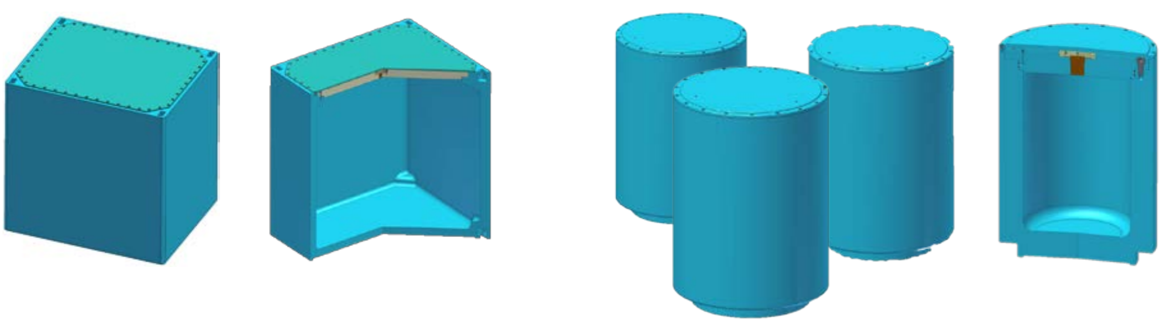

Fig. 1. Cuboidal and cylindrical DCICs (BlueBox®[1] and BlueBarrel)

Depending on the activity of the radioactive waste and thus on the shielding requirements for the package a container design with a variable wall thickness would be favorable. Considering the proposed waste loading method the lid system has to be designed to be flexible to the various requirements like lid size, shielding and leak tightness. Furthermore various operations of a loaded package are usually undertaken like drying of liquid containing waste and measuring/monitoring which are performed through penetrations through the lid system. Further design elements relate to various conditions coming either from the operational side during loading of the package (short times for closure of the package in order to keep the dose rate for operators as low as reasonable practical, easy decontamination of the outer surfaces, easy handling etc.) and

[1] BlueBox® is a registered Community Trade Mark

during operation (e. g. venting of a package with gas generating content) as well as requirements coming from accident conditions like drops or fire (improvement of container response to accidental impacts).

THE UK MARKET AS FIRST APPROACH

The starting point for the first realization project was the market situation in the UK [3]. The UK NDA – RWM (NDA: Nuclear Decommissioning Authority) is responsible for the planning, building and operation of a Geological Disposal Facility (GDF) in the UK in order to realize the Government policy for the long-term management of radioactive waste [2]. A GDF is a facility located below ground to provide long-term isolation of high or intermediate level wastes from the human environment. Whilst plans for the construction of a GDF remain at an early stage only specifications of a generic character for the waste to be disposed and the waste packages itself are available.

To bridge the time gap until a GDF is available and in operation, it is planned to store the waste in purpose-built Interim Storage Facilities (ISFs) awaiting transport to GDF for final disposal.
The design of the DCICs requests thus a high level of flexibility and variability to cover the not yet finally defined specifications for impact scenarios for transport, intermediate and final storage outlined in the following set of drop orientations and crash sequences (Fig. 2a and 2b):

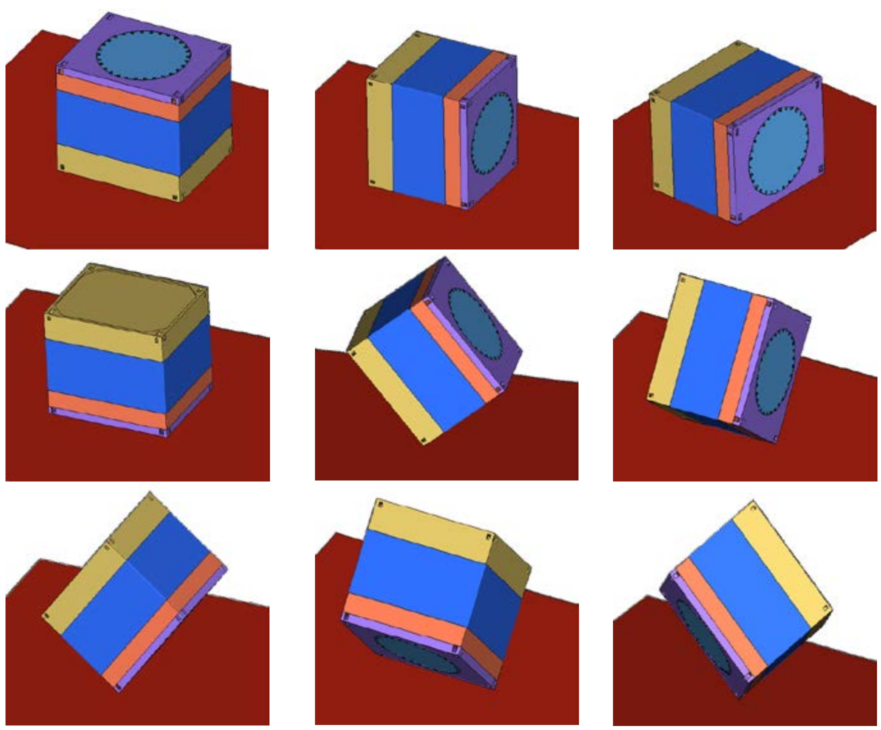

Fig. 2a. Impact scenarios for single drop tests for a cuboidal container

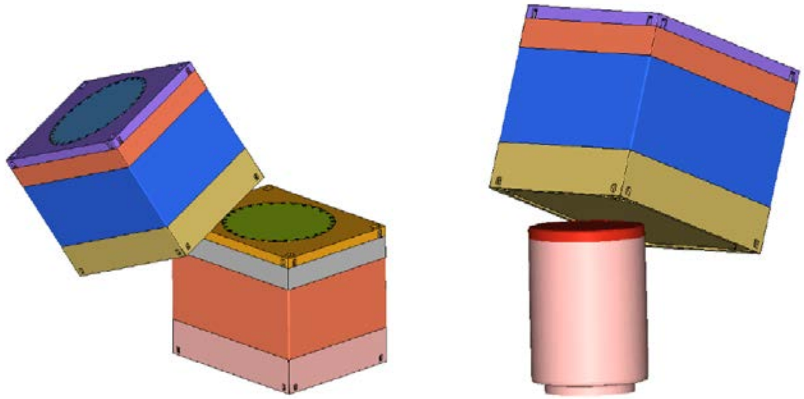

Fig. 2b. Impact scenarios for mixed drop tests

The current specifications for the design phase cover thus

- the waste to be disposed (low specific activity, surface contaminated objects),
- the transport requirements acc. to IAEA recommendations (type IP-2) and
- the operational requirements for the ISF and GDF (handling, stacking height, impact, fire, design life).

The design work so far in consideration of the above mentioned specification led to the following design (Fig. 3):

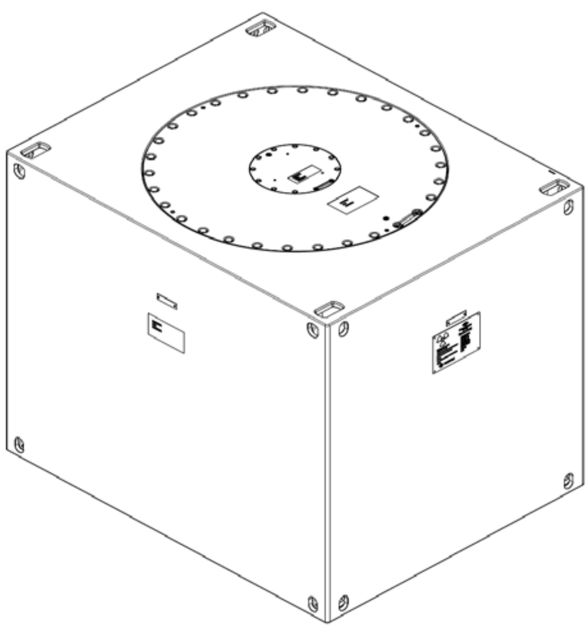

Fig. 3. BlueBox® DCIC with round opening and ISO corners

As material, Ductile Cast Iron (DCI) has been chosen for the container body as well as for the shielding lid of the BlueBox®. The main outer dimensions (L x W x H) of the BlueBox® are 1,600 mm x 2,000 mm x 1,700 mm. The container body is designed with straight walls with a wall thickness of 150 mm and a two-step round or octagonal opening for the assembly of the inner and outer lids.

The lid system consists of an even round plate manufactured of DCI. The main dimensions of this shielding lid are Ø 1,062 mm x 170 mm. During assembly the shielding lid is joined with the container body by means of bolts. The shielding lid is sealed by a set of twin seals embedded in the shielding lid. Furthermore the shielding lid has a central opening and two further openings for various operations (e. g. drying or measuring). These three openings are closed by plugs manufactured of stainless steel. All plugs themselves have a set of twin seals for leak tightness purposes. With modified plugs venting purposes of gas-generating waste during storage can be realized.

On top, an outer lid with a central plug covers the inner lid. Both are made of carbon steel joined to the container body again by bolts and equipped with a set of twin seals. Where twin seals are incorporated pressure test points are implemented in order to confirm the seal integrity through measurement of vacuum degradation in the inner space between the two O-rings.

At the container body bottom side four elevated bases with a circumferential rib are provided with a beveled diagonal inner contour. The rib is machined plain with the four bases. The elevated bases with the rib form a ridge which increases the resistance of the container against accidental impacts. Furthermore it supports self-stacking of the BlueBox® when using octagonal openings.

In each corner of the BlueBox® container body an ISO lifting point is machined in order to realize load attachment points for transport.

The dimensions of the BlueBarrel are Ø 1,200 mm x 1,700 mm with a wall thickness of 200 mm. The lid system for the BlueBarrel is comparable to the round lid of the BlueBox®, except that there is no outer lid for the BlueBarrel.

For both, cuboidal and cylindrical DCICs, the wall thickness can be varied in order to fulfill the required shielding properties. Furthermore the BlueBarrel can be equipped with an internal lead shielding (between 20 and 120 mm thick) to allow packaging and transportation of higher active materials.

A first step of the licensing procedure has been performed by NDA with the 'Letter of Compliance' (LoC) disposability assessment process as a means of supporting the UK nuclear industry's ongoing work on the conditioning and packaging of higher activity waste for disposal. Depending on the stage of the development of the packaging process, the issue of a LoC indicates [2]:

- Conceptual stage LoC (cLoC): That the proposed waste package would in principle be compliant with the generic geological disposal concept(s).
- Interim stage LoC (iLoC): That evidence has shown that the as-designed waste package would be compliant with the generic geological disposal concept(s).
- Final stage LoC (fLoC): That evidence has shown that the as-manufactured waste package will be compliant with the generic geological disposal concept(s).

For both BlueBox® and BlueBarrel the cLoC stage is completed (Fig. 4). Current work is focused on the iLoC stage for the BlueBox®.


LOC/17364646 SNT 2 Metre Blue Box (Conceptual Stage)

NDA
Nuclear
Decommissioning
Authority

Radioactive Waste Management Directorate
Building 587
Curie Avenue
Harwell Oxford
Didcot
Oxfordshire OX11 0RH
T +44(0)1925 80 2820
F +44 (0)1925 80 2832
www.nda.gov.uk

24 October 2012

Our Ref: LOC/17364646
File Ref: TPC 71 010

Siempelkamp Nuclear Technology Ltd

Conceptual Stage Letter of Compliance for the 2 Metre Blue Box waste container

On the basis of our current understanding, we can confirm that the proposed design of 2 metre Blue Box waste container would be capable of being used to manufacture waste packages that would be compatible with the requirements we see as necessary for storage, transport, handling and disposal. We would draw your attention to Assessment Report NXA/17370832, which sets out the basis for this conclusion.

Fig. 4. NDA confirmation on cLoC for the BlueBox®

Substantiation Studies

For support and substantiation of the container design various studies have been performed. They cover the shielding capabilities of the package, accidental impacts on container integrity (drop tests) and accidental impacts by simulation of a fire.

Drop Tests

The mechanical behavior of the container has to be assessed by tests defined by the IAEA resulting in a requirement for a 0.3 m drop test for the Type IP-2 container or other requirements according to the selected storage specifications [4]. The drop test specified by the licensing authority was performed according to an established test and measuring program.

The drop test sequence consisted of a 0.3 m drop test according to the IAEA transport requirements for an IP-2 package and a 5.2 m drop test according to a 3fold stackability requirement in a storage facility. Both were performed with the same box on the same day (see Fig. 5). For that reason all tests (visual inspection, ultrasonic testing, leak tests) were carried out prior to the 0.3 m drop test and then again after the 5.2 m drop test. In this respect the positive results of the whole drop test series are even more remarkable.

For both the 0.3 m drop test and the 5.2 m drop test a flat base drop orientation was selected to achieve a high load to the container body after reflections from the unyielding target, usually taken in licensing procedures for transport accident scenarios, but also for specific final repository solutions.

Fig. 5. Drop test of 5.2 m at Winfrith Drop Test Facility, UK, for the BlueBox®

The leakage rates prior to and after the drop tests were the same. Even the 5.2 m drop test itself showed no influence on the sealing mechanism – the integrity of radioactive load could be guaranteed at any time. The leak tests also showed indirectly the correct function of the bolting material. The inspections of the BlueBox® prototype after the drop test could not detect any damage with influence on the integrity of the container. All ISO-Corners maintained in excellent conditions. The circumferential rib at the container bottom side withstood the applied loads and strains without any damage.

The BlueBox® prototype proved to be capable of withstanding a free drop test according to IAEA requirements. The results of the leakage tests have shown that the integrity of the BlueBox® prototype was not affected in any way.

Various substantiation studies which took advantage of the results from the above described drop tests were performed to cover the impact scenarios shown in Fig. 2a and 2b. Parameters like drop orientation, drop height, wall thickness, package content, material properties, bolt pretension and internal pressure were varied based on a material and damage model for the DCI developed for this purpose.

The studies identified the most severe drop scenarios for single design details like a flat drop test for lid integrity. In any case the results showed no integrity loss under the unique requirements as described above, especially concerning drop tests for mixed vaults (container drops onto an another container). The drop of a BlueBox® base down on a cylindrical container top edge was identified as the most crucial one. Drop heights up to 7.5 m are manageable which is equivalent to a 4-high stacking of the BlueBox® (Fig. 6). In case of higher requirements for stacking either design changes have to be done or the specifications for accidental scenarios have to be reconsidered.

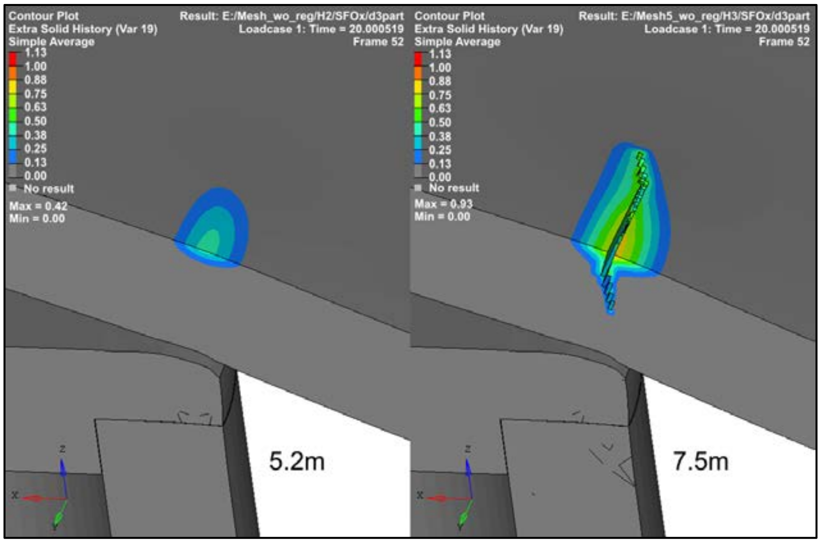

Fig. 6. Accumulated Damage for Drop Height of 5.2 m and 7.5 m for a mixed drop scenario

Fire Justification

There are no fire performance requirements for a type IP-2 package defined in the IAEA transport regulations. Higher quality packages like type B are requested to withstand a fire load of 800 °C for 30 min. duration. This requirement has well established within the international community and could be shown for the BlueBox® as manageable (Fig. 7):

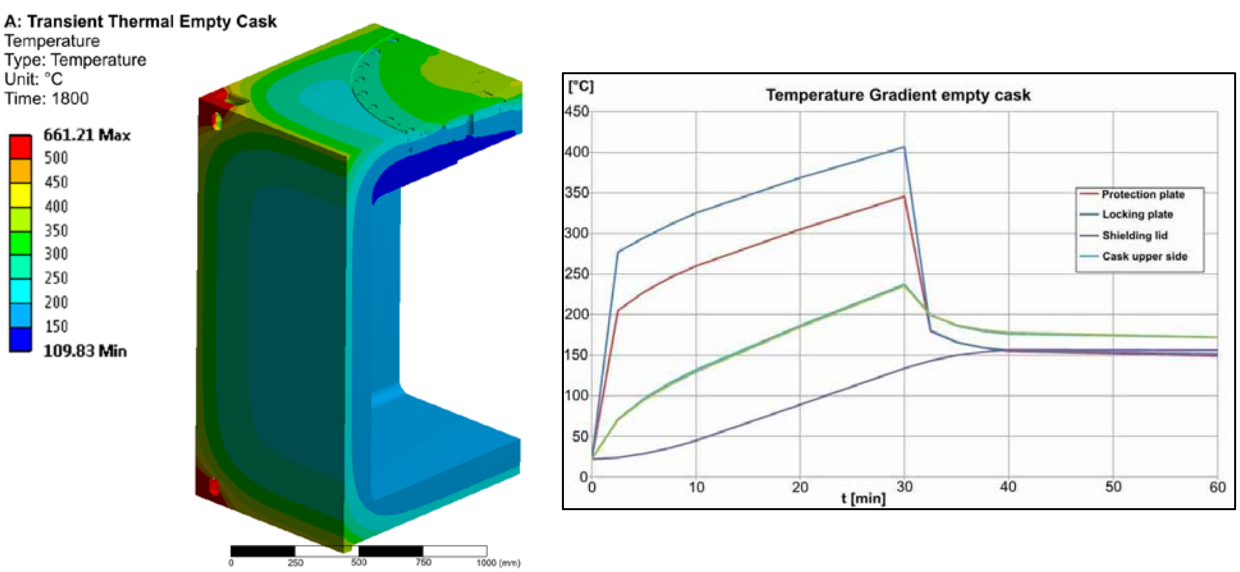

Fig. 7. Temperature gradient of the BlueBox® (quarter model) as response to an 800 °C fire for 30 min.

Higher fire performance requirements, 1000 °C for 1 h, as there are currently specified for a GDF in UK, demand for further development work, which are under intensive discussions with authorities as well as with manufacturers of sealing materials.

Present Status of the Ongoing Project Work

Within an extremely short time phase a new container concept was developed for transport and storage of radioactive waste which was successfully approved in the UK. The concept with the product name BlueBox® offers a design which is tailored to the required specific conditions. The customer as well as the licensing authority categorized it as a robust self-shielded IP-2 waste package according to the presently required classification for transport and storage of low and intermediate level waste.

At the same time as the development of a cubic disposal container, design work on a cylindrical container solution has been pushed up. The experience with the BlueBox® approval was a good example. The concept certification for the BlueBarrel type was successful, too.

CONCLUSIONS

Through technical tests, analytical work and the successfully performed design licensing process in the UK it could be approved that the developed containers for transport and storage of low and intermediate level waste completely meet even complex disposal requirements. The results demonstrate the favorable characteristics of the material DCI and the related casting process, which will facilitate the further implementation onto the international market.

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