Use of Ductile Iron for Radioactive Waste Packaging and Shielding in the United States – 17278

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ABSTRACT

Ductile Cast Iron (DCI) has been used for packaging radioactive waste in Europe and the United Kingdom for many years. The ductile iron provides many favorable properties when compared with steel and offers many advantages including:

- Monolithic structure increasing overall strength
- No welding required; no tempering or maintenance/inspection of the weld area is required
- Fast, serial production of similar containers reducing manufacturing costs
- Lower cost compared to steel or steel/lead composites
- Good corrosion resistance even when uncoated
- Can be coated or plated to provide suitable surface for decontamination
- Flexibility in design due to the manufacturing process permits a variety of shapes and very large size container possibilities
- Hazardous materials not needed or used for shielding

The flexibility in design will help generators find viable and more cost effective packaging options for radioactive waste. The package is conformed to the waste instead of conforming waste to the package.

Commercial utilities often replace radioactive components which are too large for conventional packaging and have dose rates too high for flexible wraps while plant schedule and physical configuration won't allow for component segmentation. This is one situation where the use of ductile iron can be used to provide a packaging solution. By assessing the radiological characterization and component size and weight, ductile iron can be cast into certified containers to easily package, ship and dispose of the waste in a cost effective manner.

INTRODUCTION TO DCI

DCI has been used for certified packaging for radioactive waste in countries outside of the United States for many years. In the United Kingdom for example, the ductile iron is specified for use in the fabrication of three (3) cubic meter robust shielded boxes. The Waste Package Specification, WPS 381, *Waste Package Specification for 3 cubic metre robust shielded box waste package for transport as part of a Type IP-2 package,*[1] has been issued by Radioactive Waste Management (RWM), and is part of the group's overall Waste Package Specification and Guidance Documentation (WPSGD).

WPS 381 is applicable to radioactive waste that has been classified as Intermediate Low Level Waste (ILW) which is generally analogous to waste that would be classified as B and some Class C in the United States and can be packaged into Industrial Package 2 transport packages.

In Germany, rectangular and cylindrical containers are cast from DCI into standardized shapes for radioactive waste that has been conditioned for ultimate disposal at the Konrad repository.[2]

For more robust radioactive material packaging requirements in Europe, the CASTOR® (**Ca**sk for **s**torage and **t**ransport **o**f **r**adioactive material) container is used for the transport and interim storage of spent fuel elements and vitrified high active waste. All CASTOR® types have the same basic concept. The transport container is a thick-walled (approx. 450 mm) body constructed of cast iron with spheroidal graphite which provides extremely high strength and toughness. In addition, the cast body wall is provided with through axial boreholes filled with plastic rods. The plastic inserts are used as a neutron shield. The bottom and cover also have such inserts. The fuel elements are held in a rack of boron steel; a neutron absorbing material. The container is closed by a multiple cover system. This consists of an approx. 340 mm thick primary cover and an approx. 130 mm thick secondary cover made of special steel. The two overlying covers are bolted firmly to the container body. The sealing effect of the covers is ensured by special metallic packings. A protective steel plate screwed over the cover system protects this against mechanical impacts and humidity. Lifting lugs are attached to the top and bottom of the container.[3]

In Sweden and Finland, spent nuclear fuel is encapsulated in cast iron and copper canisters in order to be transported to the Spent Fuel Repository. The canisters are nearly five meters long and just over one meter in diameter. The inside of the canister consists of an insert of nodular cast iron which provides the structural integrity required. The canister shell consists of a bottom plate, a tube and a lid and forms a five (5) centimeter thick copper casing to protect against corrosion.[4]

Outside of the United States, the thick walled DCI containers are used in combination with other materials, as previously mentioned, to provide packaging for the safe transport and storage of spent nuclear fuel. In the United States, thin walled stainless steel inserts are used for interim dry storage in concrete storage facilities. The only exception to this is at the Surry Nuclear Plant which utilizes a CASTOR DCI canister. More work will be required in the United States before spent nuclear fuel, stored in stainless steel canisters can be shipped to an interim or final repository.

MATERIAL PROPERTIES

Ductile Cast Iron, also known as nodular cast iron, spheroidal graphite iron, and spheroidal graphite cast iron is a type of graphite-rich cast iron developed in 1943 by Keith Millis.[5] While most varieties of cast iron are brittle, ductile iron has much more impact and fatigue resistance, due to its nodular graphite inclusions. Ductile iron is not a single material but part of a group of materials which can be produced with a wide range of properties through control of their microstructure. The common defining characteristic of this group of materials is the shape of the graphite. In ductile irons, graphite is in the form of nodules [Figure 1] rather than flakes [Figure 2] as in grey iron. Whereas sharp graphite flakes create stress concentration points within the metal matrix, rounded nodules inhibit the creation of cracks, thus providing the enhanced ductility that gives the alloy its name and provides an extremely well suited material for radioactive waste containers.

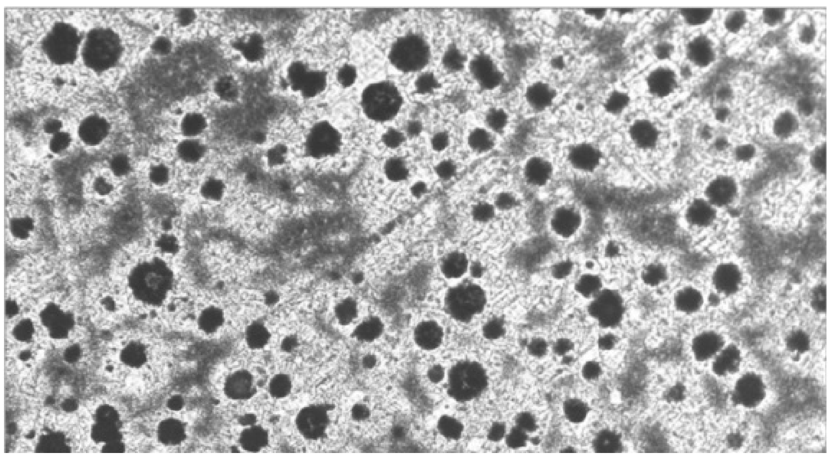

Figure 1 DCI Nodular Microstructure [6]

Figure 2 Grey Iron Flakes [7]

The containers are carefully cast from molds created from patterns creating a monolithic structure that provides for great strength both in the container and all lifting and tie-down points. The DCI container is free of hazardous materials, such as lead, and in addition since welding is not required, the initial purchase cost for DCI containers is often less than similar containers, and preventive maintenance is minimized resulting in reduced total cost of ownership. Adding to the total cost of ownership is the fact that when the container/material is no longer needed, it can be re-used or disposed of after free release without the issues encountered in comparable steel/lead containers.

The material can be cast into a variety of shapes, thus allowing for flexibility in the design of the containers and allowing the container to conform to the waste instead of the waste conforming to the container. The material density is approximately 7.3 grams / cubic centimeter (g/cc) which compares similarly to steel (7.8 g/cc) for shielding properties. No welding of the material is required and handling features (Lifting and Tie-Down Lugs) are incorporated into the casting.

APPLICATIONS FOR DCI

In the United States, the Department of Transportation (DOT) is the regulatory body for Industrial Packages (IP) and Type A containers to be used as radioactive waste class 7 packages. Requirements are found in Subchapter C of 49 CFR, *Hazardous Material Regulations*, and more specifically in 49 CFR 173, *Shippers – General Requirements for Shipments and Packaging*.

Radiological surveys and characterization of the waste will provide the waste classification and for purposes of packaging, the DOT quantity and type. One of the first tests of suitability of DCI for a particular radioactive waste form will be a determination of the waste form's type.

IP and Type A containers are typically used for radioactive waste that is typed as Limited Quantity (LQ), Low Specific Activity (LSA), Surface Contaminated Object (SCO). DCI will be used for those wastes with higher activity and dose rates but still meeting the requirements for DOT regulated packages. Compliant waste for the DOT regulated package is limited to a radiation level of 10 mSv/hr (1000 mrem/hr) at three (3) meters from the unshielded waste object or collection of waste objects.

Commercial utilities in the United States often replace components which are too large for conventional packaging such as a 20' cargo container. In many instances, a soft-sided wrap that meets IP-1 requirements could be used however, the wrap will not provide any shielding and the waste, to be packaged into the IP-1 wrap, must be DOT typed as LQ, LSA-1 or SCO-1.

The component could be segmented and sized appropriately to fit within a conventional container; however the utility may have constraints in building footprint to perform the segmentation work and scheduling pressures.

In addition to these constraints, the utility will need to consider the impact of segmentation work on plant radiological conditions and the ALARA (**A**s **L**ow **A**s **R**easonably **A**chievable) program and goals. The DCI container can alleviate concerns with worker TEDE (**T**otal **E**ffective **D**ose **E**quivalent) exposures as the component can be placed directly in the container; greatly reducing handling time, creation of airborne contamination and providing instant shielding when placed into the container.

In a situation such as this, the flexibility of casting DCI can provide the utility a regulatory compliant package packaging solution. By assessing the radiological characterization and component size and weight, and DOT regulations, DCI is cast into certified containers [Figure 3] to easily package, ship and dispose of the waste in a cost effective manner, with a relatively short lead time as the container is cast from a single material.

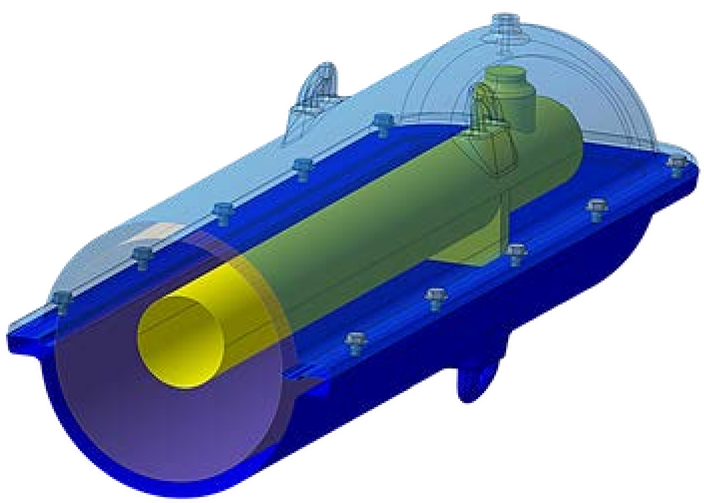

Figure 3 Cutaway of IP-2 Package for Large Component

Another suitable application of DCI attributable to low cost, high shielding properties and ability to cast into any thickness would be for shielding that is used during onsite radioactive waste transfer and processing activities. The Process Shield [Figure 4] is cast in a size with adequate wall thickness to emulate the shielding typically provided by conventional casks. This includes shielding thicknesses similar to Type B casks. A Process Shield can be sized to accommodate large waste liners that would not fit within a Type B cask. Thus a utility can use a single Process Shield as needed to perform many onsite activities that previously would require multiple casks, and long lead times.

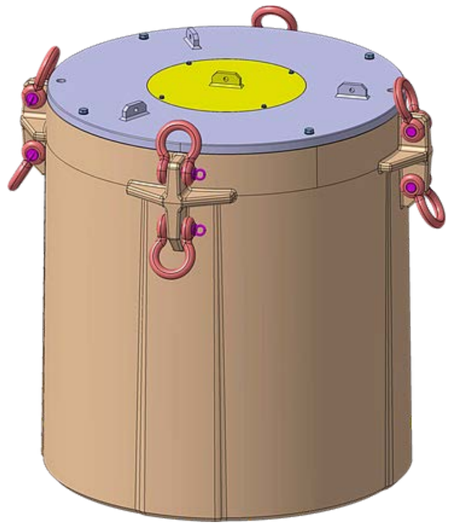

Figure 4 Process Shield

The Process Shield can also be designed and tested to meet 49 CFR 173 requirements for a Type A cask.

CONCLUSIONS

While DCI radioactive waste packages are well known and used in a variety of configurations around the world the application of the material for waste packages has been limited within the United States. Although disposal practices differ and more radioactive waste is sent for direct disposal in the United States, there are many situations where DCI packages and shielding make sense for the utility and waste generator.

REFERENCES

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