

## **Comparison of German and American Fabrication Standards for Transportation and Storage Containments of High Level Radioactive Material Type B Packages – 15055**

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### **ABSTRACT**

As the competent authority for the evaluation of German radioactive material (RAM) transport and storage packages, BAM (the German Federal Institute for Materials Research and Testing) has evaluated various international cask manufacturers regarding compliance with the German Type B(U) licensing requirements. The US NRC has recommended paragraphs in the ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Division 3, as the measure to quantify the safety requirements of the US regulations regarding fabrication of RAM transportation and storage containments. The objective of this study is to compare the fabrication criteria of the German Dangerous Goods Procedural Rules (BAM-GGR) and the German Institute for Standardization (DIN) with the US quantitative measures for fabrication of RAM package containment vessels. This comparison will cover major similarities and differences between the requirements of the German standards and the ASME Code requirements for Type B package containment fabrication QC (quality control). While the material most often used for German RAM containment applications is ductile cast iron (DCI), in the US forged austenitic stainless steel is typically used. This study focuses on fabrication QC measures required to ensure reproducible and acceptable properties for DCI containments.

### **INTRODUCTION**

Shipments and storage of high-level radioactive materials require the use of highly robust Type B packages, which are designed, fabricated, and tested to prevent the release of contents under both normal and hypothetical accident conditions, as prescribed in the applicable US regulatory documents [1], [2]. The BAM recommendations for DCI processing for German casks are found in BAM-GGR 007, *Guideline on the use of spheroidal cast iron for transport and storage casks for radioactive materials* [3] and in the standard DIN EN 1563, *Spherical Graphite Cast Irons* [4].

The above German standards are evaluated relative to the requirements of the ASME B&PV Code, Section III, Division 3: *Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste* [5]; ASME Code Case N-670-1, *Use of Ductile Cast Iron Conforming to ASTM A874/A 874M-98 or JIS G5504-2005 for Transport and Storage Containments* [6]; and ASME Standard SA-609/SA-609M, *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof* [7]. The Code Case N-670-1 was approved by ASME on January 4, 2008 for use in meeting the ASME B&PV Code, Section III, Division 3 requirements for DCI fabrications. The ASME Standard SA-609/SA-609M covers in detail the allowable procedures for pulse-echo ultrasonic examination (UT) of DCI castings. In Germany, independent experts supporting BAM have reported favorable results for the NDE of DCI thick-walled cask bodies using UT methods for flaw detection [8]. While there is no German equivalent standard to ASME SA-609/SA-

609M, BAM has verified and certified German NDE equivalence with ASME standards in satisfying German licensing compliance for DCI storage and transport casks [14].

The comparisons presented in this study focus on quality controls required for fabrication of DCI containments for Type B packages, to verify compliance with required procedures and practices. Key QC elements to be covered include casting plans to ensure process reproducibility by identification of essential process parameters, macro-examination/mechanical testing of core samples, and nondestructive examination (NDE) of prototypes and production units for compliance with the established acceptance criteria.

### **GERMAN REGULATORY GUIDE, BAM-GGR 007**

In Germany, BAM-GGR 007[3] is the regulatory guide that describes the fundamental aspects that should be considered for design and fabrication of DCI containment structures. The approval of the BAM for the use of spheroidal graphite cast iron as the material for the sealed containment of RAM casks is based on the baseline expert report published in the BAM Official Gazette in 1985 [9]. The recommendations of the baseline expert report were verified taking into account the experience of BAM in testing construction types and the state-of-the-art currently achieved in the use of spheroidal graphite cast iron. The results of this verification are specific recommended criteria for the fabrication requirements of these casks, established as proof of safety against ductile and brittle failure due to accident conditions. The BAM over the years has documented and analyzed extensive material test reports, and the results of these studies are included in QC guidelines for the manufacture of casks. The guidelines identify safety-relevant process controls in the forms of material data sheets, material examination/testing, test sequences during production, with the appropriate fabrication process parameter specification and controls.

The mechanical properties of castings depend to a large extent on the product form section thicknesses, since for thicker walls and slower cooling rates, slower crystallization and transformation processes take place. For the slower cooling rates, the following undesired microstructural details may occur: more graphite degeneration, grain boundary carbides, and seams, leading to increased segregation of properties. Thus for casks with thick wall sections, special attention must be given to QC measures to ensure reproducible properties for serial production. This is why “in-line” tests and examinations of production units are required for the qualification of the German cask material properties. Design certification tests on models alone are insufficient, without thorough QC analysis of essential production variables. The following items must be examined and controlled, with acceptable tolerance bands, during manufacture of DCI containment product forms:

- Melting process
- Chemical composition
- Segregation behavior
- Dimensional limits
- Localized mechanical properties
- Localized hardness and resulting low toughness, which increases with the amount of eutectoid carbide (pearlite) in the microstructure.

Unlike pressure vessel applications, involving forged pieces welded together, thick-wall DCI parts are cast in one piece, and may contain volumetric three-dimensional defect zones without

thorough QC analysis of the above. In order to validate critical values of essential manufacture variables, the German fabrication process for casting QC includes extraction of large coupons from the production prototype wall sections for testing and metallographic evaluations [9]. Guidelines for coupon extraction, including coupon dimensions and location within the casting, and test methods for specimens are provided in Standard DIN EN 1563, paragraph 8 [4].

Since the mechanical properties of nodular cast iron vary widely depending on the fabrication conditions, the applicant (owner), the manufacturer, and BAM determine the required QC metrics to be implemented during the manufacture of prototypes and production units. These metrics, originally provided in the baseline expert report [9], are implemented in the casting process procedures and process qualification documents, as recommended by BAM-GGR-007 [4]. The following discussion summarizes these QC metrics provided in the baseline expert report [9].

- Determination of manufacturing parameters: The procedural steps and conditions of production of the castings are provided in a BAM approved production and testing plan.
- Determination of the material specification by sampling: Typically, material characteristics are determined using integrally cast test bosses for qualification of the production castings. In addition, special oblong boring machines are utilized to sample casting walls. Appropriate mechanical material testing is performed using test specimens made from the samples.
- Metallographic evaluation is performed as dictated in the sampling plan: Samples are obtained from the cask wall centers in the lid area, bottom area, and the mid-section of each casting, if possible. The samples will be appraised with respect to metallic matrix, including graphite shape and dimensions, and focusing on any graphite separations. The percentage of Ferrite and chemical analysis of the samples will be documented. The percent Ferrite determination in DCI is an indicator of ductility and toughness.
- Nondestructive examination (NDE): NDE of each prototype casting is performed, in accordance with an approved plan and NDE specification, with acceptance criteria. NDE methods will include visual examination (VT), liquid penetrant testing (PT), and ultrasonic testing (UT).

The wall thickness dependence of nodular cast iron properties is accounted for in German standard DIN 1693, Part 2 [12]. The material parameters to be determined, using samples taken from test specimens, are defined in Part 2 of the Standard.

### **ASME CODE CASE N-670-1**

The following summarizes the ASME B&PV Code Section III, Division 3 Code Case N-670-1 [6] fabrication requirements regarding the use of DCI (wall thickness greater than 300 mm but less than 530 mm), conforming to ASTM A874M-98[10] for construction of transport and storage containments, in accordance with Subsection WB Class TC:

- The containment body shall be cast by a single pouring controlled by a casting plan to ensure reproducibility. The casting plan shall be agreed upon between the fabricator and the owner and shall be a lifetime QA record
- Tensile specimens and fracture toughness test specimens shall be taken from each containment casting or an excess length that has equivalent solidification properties

- All castings shall be volumetrically examined by UT in accordance with the ASME B&PV Code, Section V, Article 5, Paragraph T-571.4 Castings [11]. The quality levels of ASME SA-609, Tables 3 and 4 [7] shall be applied as acceptance standards (quality level 4 for thicknesses greater than 100 mm)
- In addition to the above quality level requirements, for both straight beam and angle beam UT, the acceptance criteria of (-a) through (-e) shall apply for discontinuity dimensions and location in the castings
- The ASME B&PV Code Section V, Paragraph T-571.4 Castings [11] invokes the majority of ASME SA-609 for standards and procedures for the UT pulse-echo technique for DCI castings by the longitudinal-beam technique. Specific procedural requirements are provided for two separate calibration techniques: (A)-calibration using a series of test blocks containing flat bottomed holes and (B)-for angle beam testing, calibration using a back wall reflection from a series of solid calibration blocks
- For critical casting areas that cannot be effectively examined by UT using a longitudinal technique, ASME SA-609, [7] “Supplementary Requirements,” provides recommendations to achieve effective examination
- Surface examination shall be performed of all external and accessible internal surfaces, except threaded surfaces, by liquid penetrant (PT) or magnetic particle (MT), after final machining.

### **COMPARISON OF FABRICATION QC FOR THE GERMAN STANDARDS AND THE ASME CODE, SECTION III, DIVISION 3**

Table I compares the major similarities and differences of the German and US fabrication criteria for DCI containments. The fabrication criteria provided in the reference documents are the following:

- Casting plans, including manufacturing process parameter specifications for prototypes and production units
- Material property verification of the castings, determined through metallographic examination and mechanical testing
- Nondestructive examination plans for prototypes and production units
- Nondestructive examination acceptance criteria for volumetric and surface examination
- Material specifications, including chemical composition tolerance bands.

TABLE I. Comparison of fabrication criteria for ductile cast iron containment vessels

<b>Fabrication Criteria</b>	<b>ASME Code Case N-670-1</b>	<b>BAM-GGR-007</b>
<b>Casting Plan / Specification and Manufacturing Procedures</b>	Requirements of ASME B&PV Code Section III, Division 3, Code Case N-670-1, and ASTM A 874 (American Society for Testing and Materials) [10] to be included in Procurement Documents- Lifetime QA records	Specified in the Procurement Document [4]. QC procedures with safety-relevant process controls [9] and required QC metrics to be determined by Package owner, fabricator, and BAM
<b>Microstructure Evaluation and Mechanical Testing</b>	Specimens taken from each casting or its excess length analyzed per ASTM A 874	Extraction of large coupons from production casting walls [4]. Determination of manufacturing parameters to be included in the BAM approved production plan [9]
<b>Nondestructive Examination of Production Castings</b>	UT, PT,MT performed per the requirements of ASME Code, Section V applicable articles	VT, PT, UT performed according to independent German expert documentation [8] according to a BAM approved production plan [9]
<b>NDE Acceptance Standards</b>	Acceptance standards applied based on quality level 4 of ASME SA-609	Acceptance criteria based on baseline expert report[9] and ongoing BAM development of acceptance principles [13],[14]
<b>Chemical Composition</b>	Specified in materials standards, ASME or ASTM	Specified in material data sheets, approved by BAM

## CONCLUSIONS

The QC aspects of the fabrication process and production quality of DCI containment vessels are very similar for German and American fabrications. In contrast, there are differences in the measures to certify compliance with the regulatory safety requirements. The major differences lie in use of the authoritative standard, the ASME B&PV Code by the American regulatory bodies as measures for satisfying the safety requirements of the regulatory documents [1], [2]. For the German fabrications, the quality and compliance assurance measures are verified by BAM or its designated experts [13]. This study concludes that from the standpoint of fabrication QC measures for high level RAM Type B DCI containments, for both German and American fabrications are equivalent in meeting regulatory safety requirements. The verification processes pertaining to fabrication QC, while different, are effective to produce highly robust packages to meet regulatory containment requirements

## REFERENCES

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