# Certification Review of the DC-1 Packaging for Transport of HEU Oxide*

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## INTRODUCTION

The Safety Analysis Report for Packaging (SARP) for the DC-1 shipping container was submitted to the United States Department of Energy (DOE) Office of Facility Safety Analysis, EH-32, in May, 1994, by the Martin Marietta Energy Systems, Inc. (MMES), Oak Ridge Y-12 Plant, through the Enrichment Oversight and Uranium Revitalization Division, NE-32, the cognizant program office at DOE Headquarters for the DC-1. The SARP was part of an application for a DOE Certificate of Compliance for Type B radioactive material packaging. The DC-1 (Figure 1) was developed out of a need to ship high-enriched uranium (HEU) oxide powder - both loose and compacted - from the Portsmouth (Ohio) Gaseous Diffusion Plant to Y-12.

The uranium oxide is stored at Portsmouth in cans that range from 5 to 8 inches in diameter. It was realized by the packaging designers and those organizing the shipping campaign that uranium stored in containers of 6 inches or more in diameter does not represent a critically safe geometry for all conceivable conditions of moderation and reflection. Moreover, it was learned that Portsmouth does not have the facilities necessary to open up the cans and repackage the oxide into smaller diameter containers, which would have simplified the transportation problem considerably.

A transport packaging for such containers, therefore, would have to incorporate special design features to ensure subcriticality and meet regulatory safety requirements. As there was no certified DOE or Nuclear Regulatory Commission (NRC) packaging that would have been suitable for the existing oxide cans, Y-12 was directed to develop a unique packaging for the particular shipping problem at hand.

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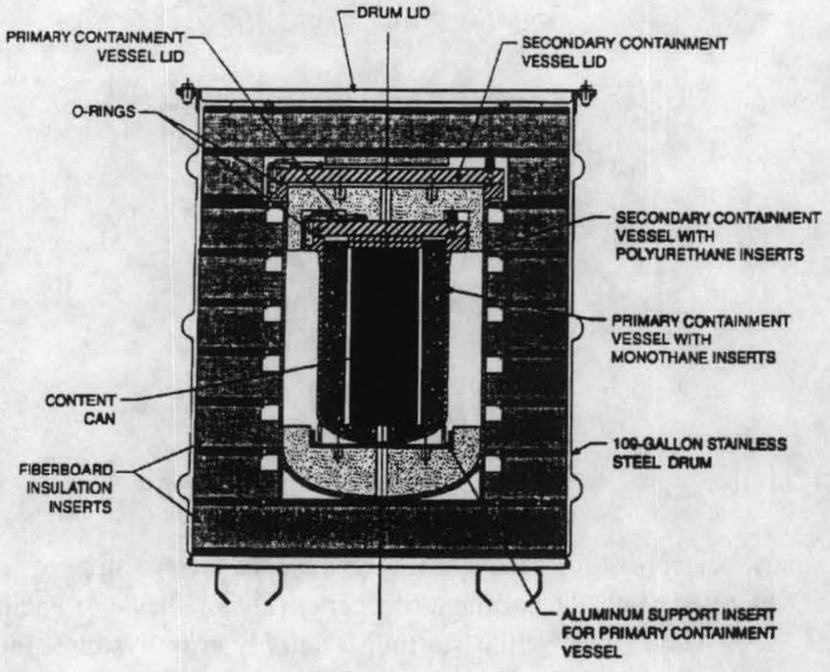
**Figure 1. DC-1 Packaging.**




## QUESTION/RESPONSE REVIEW CYCLE

The first two stages of a SARP review (referred to as the Q0 and Q1 reviews) are intended primarily to identify any missing, incomplete, or inconsistent information or data in the SARP which will be needed later by the review team to conduct confirmatory analyses. Any obvious flaws in analytical approach, unjustified assumptions, etc., are also identified at this time. The Q0 list of questions developed by the review team provides relatively rapid feedback to the applicant on any deficiencies in the SARP documentation or analytical approach; Q1 questions are similar to Q0s but follow at a later date. Q2 and subsequent questions typically are generated as a result of confirmatory analyses. In each case, the applicant provides responses in the form of page changes to the SARP.

The technical review and confirmatory analysis of the DC-1 SARP were assigned by EH-32 to Lawrence Livermore National Laboratory (LLNL), with Eagle Research Group, Inc., (ERG) providing project management and coordination support. LLNL assembled a team of seven individuals to provide expert review of the various chapters of the SARP, draft review questions, and assemble a Technical Review Report at the conclusion of the review.

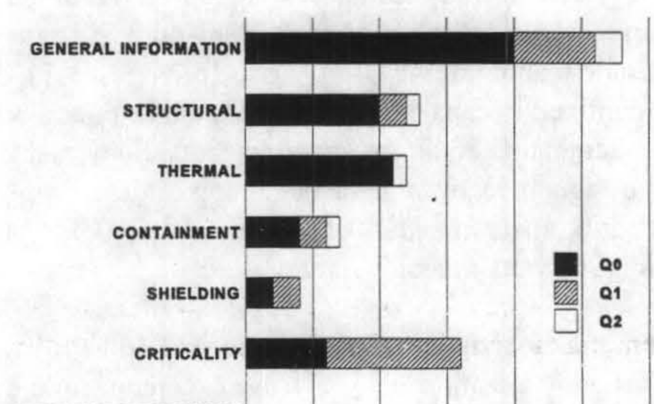
The Q0, Q1, and Q2 lists of questions generated during the DC-1 review were each provided informally to Y-12 prior to formal transmittal by EH-32. This was done to give the applicant a chance to review the questions and seek clarification, if desired, thus minimizing the possibility of misunderstanding a question's meaning or intent and the resultant waste of time and effort on the part of both applicant and reviewer. Two conference calls were held with Y-12, EH-32, and the review staff to clarify the intent of several Q1s; otherwise, no rewording of questions was necessary prior to formal transmittal to Y-12 through the cognizant DOE Headquarters program office.

Q0 questions were provided informally to Y-12 about 4 weeks after receipt of the SARP at LLNL (June 2, 1994). This was a somewhat longer time than is typically spent on the Q0 stage of review, and the relatively large number of questions (65) reflects this (Figure 2). A number of the Q0s addressed inconsistencies throughout the SARP concerning the exact identification of the contents, including weights, chemical and physical forms, isotopic distributions, and moisture contents. It was clear that the responses to the Q0s would entail numerous page changes throughout the SARP.

After receipt of the Q0s and during the formulation of responses, Y-12 asked EH-32 if the initial response to the questions could be in the form of a separate question-response matrix document. This document would list the text of each question, a summary of the response in enough detail for the reviewers to assess its technical adequacy, and an indication of whether a SARP page change would result from the response. This method of response, Y-12 pointed out, would provide substantive responses to the reviewers in a timely fashion while avoiding, at least until the end of the SARP review process, the tedious and time-consuming task of generating numerous SARP page changes and satisfying the requirements of the Y-12 document control system.

After consulting with LLNL and ERG, EH-32 agreed to this arrangement, with the understanding that a final, revised SARP with all indicated corrections satisfactorily completed must be submitted to and reviewed by EH-32 before a certificate could be issued. This system worked quite well; the matrix documents submitted by Y-12 were

**Figure 2. Number of Review Questions Issued.**



well organized and easy to follow, and the responses to the questions were detailed enough to give the reviewers a good basis for making a preliminary judgment of technical adequacy. A faster turnaround of responses also meant that the particulars of the design review stayed fresher in the reviewers' minds, with little or no time having to be spent "getting back up to speed." The efficiency of this system, with its resulting time and effort savings on the part of both reviewer and applicant, was one of the reasons why this SARP review proceeded as smoothly as it did.

A partial set of responses to the Q0s was submitted to EH-32 on July 11; after Y-12 had obtained more detailed content information on the uranium oxide contents from Portsmouth, a complete set of responses was submitted on August 5. EH-32 followed with an informal transmittal of 29 Q1 questions on August 30; responses were received from Y-12 on October 24. The last set of questions - eight Q2s - was issued informally on December 15 and responses were received on January 19, 1995. Each set of responses was in the form of a revised matrix document (MMES 1995a); with the Q2 responses, Y-12 also submitted a revised SARP (MMES 1995b) with page changes reflecting the responses to all questions submitted to date.

## NOTABLE ASPECTS OF REVIEW

The DC-1 packaging incorporates several features that are unique from a DOE Headquarters certification review standpoint. These features are discussed below.

### Subcriticality and 10 CFR 71.55(c)

Under the general requirements for all fissile material packages contained in 10 CFR Part 71 (NRC 1995), section 71.55(b) states in part, "Except as provided in paragraph (c) of this section, a package used for the shipment of fissile material must be so designed and constructed and its contents so limited that it would be subcritical if water were to leak into the containment system or liquid contents were to leak out of the containment system so that . . . maximum reactivity of the fissile material would be attained." Considering the high proposed fissile loading of the DC-1 (up to 15.7 kg U-235), the fact that the uranium oxide was confined in cans of up to 8 inches diameter and could not be repackaged, and the fact that no credit for containment could be ascribed to the oxide cans, the packaging designers realized at the beginning of the design process that subcriticality could not be ensured under the conditions of 10 CFR 71.55(b) if water were to leak into the packaging containment boundary.

A possible solution to the problem lay in paragraph (c) of 10 CFR 71.55. This paragraph states that the certifying organization "may approve exceptions to the requirements of paragraph (b) of this section if the package incorporates special design features that ensure that no single packaging error would permit leakage, and if appropriate measures are taken before each shipment to ensure the containment system does not leak."

The decision was made at Y-12 to pursue certification of the DC-1 under the provisions of paragraph (c). Double containment was selected as the "special design feature" required by the regulations, with two independent, leak-testable containment vessels protecting the uranium oxide cans against water inleakage. Each of the 2 stainless steel vessels has a double O-ring flanged joint and lid secured with 12 half-inch-diameter high-strength bolts. Both containment vessels are postload leak tested before each shipment via a leak-test port located in the lid between the outer O-ring and the inner (containment boundary) O-ring.

This aspect of the DC-1 design was ground breaking for two reasons: 1) the DC-1 was the first packaging submitted for DOE Headquarters certification under the provisions of 10 CFR 71.55(c) and 2) to the authors' knowledge, no packaging has ever been certified by the NRC under this particular regulatory provision (though it is possible that no such application has ever been made to the NRC).

**Containment Vessel Fabrication**

NUREG/CR-3019, *Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials* (Monroe et al. 1984), recommends that the criticality-related welds of such containers should be based on the criteria for design, fabrication, and inspection of Section III, Subsection NG of the ASME Boiler and Pressure Vessel Code. Criticality-related welds are defined as welds included in components that are part of the criticality control for a shipping container.

The primary and secondary containment vessels used in the DC-1 packaging, however, are existing components that were designed and fabricated around 1989 on the basis of Section VIII, Division 1 of the ASME Code. At the time of the SARP review, the welds on the vessels could not be reviewed for specific compliance with Section III requirements.

On the other hand, the DC-1 containment vessels, in general, have a higher structural integrity than a Section III design. The vessel welds successfully passed all 10 CFR 71.71 and 71.73 performance requirements. During fabrication, all containment vessel welds were checked with radiography and dye penetrant techniques. The completed vessel welds and walls were hydrostatically tested at 1.5 times their internal design pressure (60 psig). The welds and seals were then helium leak checked and have been helium leak tested annually thereafter.

While demonstration of specific compliance with the requirements of Section III, Subsection NG was not practical under the circumstances, it is the conclusion of the technical review staff that effective compliance with the major requirements of the Subsection has been achieved.

## Leak Test Adapter Plate

Calculations are presented in the Containment chapter of the DC-1 SARP for the reference leakage rates for the primary and secondary containment vessel O-ring seal. The maximum permissible leakage rate corresponding to the regulatory release rate of $10^{-6}$ $A_2$ per hour for normal conditions of transport is approximately 0.5 atm-cc/sec air. This reflects the relatively low radiological toxicity of unirradiated uranium oxide. However, radiological release is not the primary safety concern for containment. Subcriticality and the requirement for exclusion of water from the containment boundary are the issues of concern. The containment boundaries must be demonstrated to be watertight (with an attendant leakage rate of approximately $10^{-3}$ atm-cc/sec air) under both normal and accident conditions of transport.

There are no direct penetrations into the primary or secondary containment boundaries that could be used as leak test ports for the fabrication acceptance leak testing of the containment system recommended in ANSI N14.5, *American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment* (ANSI 1987). Instead, an adapter plate, or test flange, is inserted between the lid and body of the containment vessel being tested and bolted into place. The bottom and top surfaces of the plate are designed to be identical, respectively, to the mating surfaces of the top of the vessel body and bottom of the lid, including the presence of double O-rings (now two sets - one in the vessel flange and one in the upper surface of the adapter plate). The adapter plate has a port that is used to evacuate the containment boundary and backfill with helium. Although leak test adapter plates are a common feature in packagings for nuclear weapons, weapons subassemblies, and components, the DC-1 was among the first packagings with this feature to be reviewed by DOE Headquarters.

The helium leak test acceptance criterion at fabrication is $10^{-5}$ atm-cc/sec. The plate is then removed, and prior to each shipment the O-ring seals on containment vessels are postload leak tested to an acceptance criterion of $10^{-4}$ atm-cc/sec air. The summation of the fabrication acceptance and assembly verification leakage rate acceptance criteria, then, is less than the required leakage rate to demonstrate watertightness of the containment.

ERG and LLNL reviewed the N14.5 Standard to see if there was any guidance concerning the use of adapter plates in leakage testing, and in particular to see if there was any language in the Standard that specifically prohibited the use of adapter plates. Paragraph 6.3.1 on containment system fabrication verification states, "Before first use, each reusable containment system shall be assembled *as for shipment* (emphasis added), except that the radioactive contents may be simulated by nonradioactive contents, and tested to show that it is either leaktight or has a release or leakage rate less than or equal to the maximums shown in 5.2 or 5.3." The words *as for shipment*, it was thought, tended to indicate that leak testing with adapter plates was unacceptable, as the DC-1 was not shipped with the adapter plate in place.

However, paragraph 6.3.1 goes on to say, "To the extent possible, all joints and seams on the containment system shall be tested in the fully assembled state. In some cases, the testing of the joints and seams may have to be performed at the subassembly or component level to permit adequate access to and testing of the area." The use of an adapter plate in this circumstance can be understood to represent leak testing of the containment boundary of the DC-1 at the subassembly or component level.

It is the opinion of the authors that there is nothing in the ANSI N14.5 Standard that specifically prohibits the use of an adapter plate in the leak testing procedure for the DC-1. However, the Standard never specifically addresses adapter plates, and it is the authors' understanding that the N14.5 Subcommittee did not have adapter plates in mind when it drafted the language of the Standard. The N14.5 Subcommittee currently is addressing this issue.

## CONCLUSION

The DC-1, which received a DOE Certificate of Compliance in April 1995, represents the fastest comprehensive SARP review and packaging certification (11 months) by DOE Headquarters since the centralization of the packaging certification function in 1986. The next fastest packaging certifications include 14 months for the Shippingport reactor vessel and 26 months for the Mound 1kW packaging for heat-source plutonium.

A number of factors affect the speed with which a packaging is certified: the quality and completeness of the SARP, the design margins inherent in the packaging (which determine the level of detail of confirmatory analyses that must be performed), the priority placed on the SARP review by EH-32 (which is based on the review staff workload plus any agreements reached between EH-32 and the cognizant program offices), the timeliness of the applicant's responses to review questions, and the completeness and adequacy of those responses. Of all those factors, only the SARP review priority is within the control of EH-32.

In the case of the DC-1, the SARP review and responses to review questions had a high assigned priority both at LLNL and Y-12, the packaging incorporated significant margins of safety, the SARP and associated documentation were of high quality, and the applicant's responsiveness to the review questions was excellent.

## REFERENCES

American National Standards Institute, *American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment*, ANSI Standard N14.5 (1987).

Martin Marietta Energy Systems, Inc., *Comments and Responses for the DC-1 Safety Analysis Report for Packaging, Y/LF-467, Revision 0 (Docket 94-12-9862)*, Y/LF-497, Revision 3 (1995a).

Martin Marietta Energy Systems, Inc., *Safety Analysis Report for Packaging, Oak Ridge Y-12 Plant, Model DC-1 Package With HEU Oxide Contents*, Y/LF-467, Revision 1 (1995b).

Monroe, R. E., Woo, H. H., and Sears, R. G., *Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials*, NUREG/CR-3019, Lawrence Livermore National Laboratory, Livermore, CA (1984).

U.S. Nuclear Regulatory Commission, *Packaging and Transportation of Radioactive Material*, Code of Federal Regulations, Title 10, Part 71, Office of the Federal Register (1995).