THE DT-19 CONTAINER
DESIGN, IMPACT TESTING AND ANALYSIS

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ABSTRACT
Containers used by the Department of Energy (DOE) for the transport of radioactive material components, including components and special assemblies, are required to meet certain impact and thermal requirements that are demonstrated by performance or compliance testing, analytical procedures or a combination of both. The Code of Federal Regulations (CFR) Part 49, Section 173.7(d) stipulates that, 'Packages (containers) made by or under direction of the U.S. DOE may be used for the transportation of radioactive materials when evaluated, approved, and certified by the DOE against packaging standards equivalent to those specified in 10 CFR Part 71.'

This paper describes the details of the design, analysis and testing efforts undertaken to improve the overall structural and thermal integrity of the DC-19 shipping container.

INTRODUCTION

As part of the effort undertaken to recertify the DT-19 shipping container, it became necessary to modify the top insulation in order to minimize the thermal effects at the inner container top flange.

The original DT-19 container is shown in Figure 1. This container consists of a welded stainless steel removable head drum with a stainless steel inner container surrounded by several fiberboard inserts reinforced with plywood rings. Containment of the contents is maintained by the use of ethylene-propylene O-rings between the bolted lid and flange of the inner container. The top removable plate and ring fiberboard inserts are reinforced on each side with plywood to improve the stiffness and to aid in the insertion and removal of the inner container assembly.

A 9 meter (30 feet) drop test was performed on the original configuration of the container in the attitude shown in Figure 2. Prior to the drop test on this unit, ten (10) external thermocouples and internal temperature recording strips were attached to the inner container in the vicinity of the lid/flange interface. Following the drop test as per 10 CFR 71, Hypothetical Accident Conditions, the container was thermally tested in a furnace.

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The need for redesign became apparent when the results from the thermal test presented some concerns in the thermal/time response of the container. During the thermal test and immediately upon removal from the furnace, several thermocouples recorded readings significantly above limits normally established for the O-ring material in the top flange of the inner container. Upon review of the thermal and structural deformation data, it was hypothesized that the interface between the top and ring insert plywood rings may have separated as result of the loads of the preceding impact test. This separation exposed the inner container flange to the 800˚C plus outer container surface temperature and to the combustion gases generated by the burning Celotex™.

Subsequent analysis that simulates the drop testing of the original configuration in the attitude shown in Figure 2, substantiated the hypothesis that led to the high temperatures in the flange of the inner container. The configuration of the interior of the container as determined by the impact analysis is shown in Figure 3.

**DESIGN AND DROP TESTING**

Two concepts were generated to improve the thermal boundary design, while maintaining or improving the structural performance of the shipping container in response to impact loading. It was determined that modifications of the top Celotex™ and ring inserts near the top flange of the inner container were the best solution that minimize the impact to existing production hardware. These concepts as well as the original configuration are shown in Figure 4. The heavy lines shown in these figures represent the complete insert assembly and they define the surfaces where relative motion is possible. Each new concept had a portion of the top and ring Celotex™ that overlap the other in the vertical direction. This was done to prevent the generation of gaps and the subsequent opening at the insulation inserts as result from impact loading associated with the drop tests. Concept 1 had the overlap located above the inner container flange while Concept 2’s overlap occurred below the flange.

Following guidance provided by the Nuclear Explosives Safety Division (DOE) on thermal testing document, A Combination Test/Analysis Method Used to Determine Compliance to DOE Type B Container Thermal Test Requirements, February 1992, a program was implemented to assess the structural performance of the container to an impact environment associated with the most severe orientation at impact. This program minimizes the total cost and effort required for testing several containers for each of the concepts to be evaluated.

Computer simulation of the drop tests was performed on the original as well as the two new configurations. Figure 5 shows the structural models near the top flange of the inner container for each of the cases analyzed. Results of the analyses on Concept 2, indicate that no internal gaps are generated from the drop tests stipulated by the Hypothetical Accident Conditions in 10 CFR 71. The orientation of the container at impact is the center-of-gravity over top flange/lid interface. It was chosen because analysis and testing of the original configuration has shown that impact in this attitude results in the generation of internal gaps in the insulation inserts. The high temperatures recorded near the top flange/lid interface of the inner container are the result of these gaps during thermal testing.

Results of the analysis indicate that the drop test generates gaps in the insulation inserts.

Following the drop test, the container was subjected to a puncture test, thermal test, leak test and water immersion. Results from these sequence of tests were positive suggesting that the performance of Concept 2 is adequate, and meets the design and criteria requirements for certification.

Figure 5 shows the deformed configuration after the drop test in Concept 2 in the oblique attitude shown in Figure 1. Figure 6 shows some quantitative information of the deformed shape of the container in the area of impact.
COMPUTATION AND ANALYSES

The numerical analysis of the impact problem on the Concept 2-DT-19 container has been performed using the explicit finite element computer program LS-DYNA3D® Version 930.

The structural model was generated using the program LS-INGRID³, and the post-processing of results was done using LS-TAUROS⁴. The numerical computation was done on a SGI INDIGO-1 workstation.

The symmetrical half model of the container has 22,785 nodes, 13,035 8-node solid elements, 5,046 shell elements, 33 contact surfaces. The model has been discretized onto 23 material components (to facilitate post-processing). Figure 7 shows the cross-section view of the structural model for Concept 2.

The metallic material models used in the analysis follow an elastic-linear plastic (bi-linear) stress-strain relationship with a non-zero tangent modulus calculated as a function of the ratio of stress at and strain at failure. Isotropic hardening and isothermal conditions are assumed. All the material used in the analysis are assumed to be isotropic and homogeneous.

The bolts in the exterior flange/lid interface are discretely included in the model. A failure material model is used for the material constitutive relation for these components. Failure is based in the exceedence of the effective strain relative to the ultimate strain that is determined in uniaxial testing conditions. The program automatically removes elements that meet the failure criteria from the model. The external lid and the exterior cylindrical shell also use this material model with failure.

The fiberboard that envelopes the interior container is modeled as a three axis uncoupled material model. Curves that described the average stress as function of volumetric strain are directly input to the analysis program. These curves are fitted using a single element model and are based on uniaxial compression test of the material.

The Foam and Monothane™ inserts within the inner container are modeled as elastic-linear plastic materials. Input data that describe the stress-strain relations is taken from Ref.5.

The payload and the unyielding target surface are modeled as rigid elements. A "dummy" contact surface is defined around the target for display purposes.

All the metallic components of the container are made of 304L stainless steel. The fiberboard is a cellulosic fiber insulation board with a density of 15 pcf. The foam is a medium density flexible polyurethane, and the Monothane™ is a solid polyuretane.

The impact problem is an initial velocity problem with velocities in the entire body prescribed at an instant in time just before contact with the rigid surface. Effects of gravity are included in the solution.

Results of the simulation compare well with the experimental drop test. The geometry of the exterior of the container as calculated is given in Figure 8. Figure 9 shows analysis results for both, the original configuration and Concept 2. The results based in the original configuration show that there is a clear path for the free passage of hot combustion gases at a point 180 degrees away from the point of impact near the flange/lid interface of the inner container. Results based in Concept 2 geometry show that this free path has been eliminated from the deformed configuration.

CONCLUSIONS

This paper reinforces the fact that a program based in a combination of analysis and testing represents a cost effective, predictable, and fast method for the qualification of this class of containers. This concepts when extended to more complex containers become more attractive as the cost of testing and fabricating these prototypes can be quite high.

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REFERENCES


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