ANALYSIS OF THE DHLW CASK UNDER NORMAL AND HYPOTHETICAL ACCIDENT-CONDITION LOADS WITH INITIAL PRESSURE*

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Abstract

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The paper describes analyses performed for the Defense High-Level Waste (DHLW) cask design that establish an upper limit of 700 lbf/in^2 (1 lbf/in^2 (g) = 6.895 × 10^3 Pa) for the cask maximum normal operating pressure (MNOP). Analyses of the cask with this MNOP as an initial condition show that for both normal and hypothetical accident conditions of transport, the stresses are within allowable values.

The Defense High-Level Waste (DHLW) cask was designed (and initially analysed) for the transportation of borosilicate glass waste forms from the Defense Waste Processing Facility (DWPF). The cask is also being analysed for the transport of remote-handled transuranic (RH-TRU) wastes from United States Department of Energy (DOE) sites to the Waste Isolation Pilot Plant (WIPP). The high level glass wastes and the RH-TRU wastes differ in many respects, including physical form, maximum activity, isotope distribution and maximum heat output. One of the major differences is that the RH-TRU wastes include organic materials and cemented wastes which can produce gas through mechanisms such as radiolysis, bacterial decay and thermal decomposition, while the glass waste forms produce no gas.

The canister in which the RH-TRU wastes will be packaged will incorporate a filtered vent allowing the gas produced by the wastes to reach an equilibrium pressure inside the cask. Analysis of the cask design for transport of these wastes, therefore, must assess the effect of internal pressure during normal and hypothetical accident conditions of transport. Where stresses are elastic, the pressure effect is linear and can be added to the analysis by superposition.

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To determine the maximum normal operating pressure (MNOP), the cask design was analysed following American Society of Mechanical Engineers (ASME) pressure vessel design rules. The regulatory normal and hypothetical accident conditions were divided into appropriate ASME Service Level loads. Test and design loads were also specified. A detailed load histogram, including all combinations of normal conditions of transport environments, was derived for ASME Service Level A pressure vessel analysis.

All critical areas of the cask containment boundary were examined for the effect of each specified peak load or load combination, as well as for the effect of repeated load sequencing from the loading histogram. Stresses and deformations were compared to appropriate service-level allowables. Analysis results for the normal conditions of transport indicate Service Level A loading to be the controlling factor in establishing the MNOP.

The effect of pressure on the cask during normal and hypothetical accident drop events was studied, including (1) the 30 ft bottom-end flat drop, (2) the 30 ft closure-end flat drop and (3) the 1 ft bottom-end flat drop, all onto an unyielding surface.[1] The effect of internal pressure on the other drop events was assessed by comparing the effects on these three cases with the maximum stresses achieved on the other drops. The stresses on all the drop events are well below the allowables and can accommodate the maximum change found on the three analyses performed. The study concludes that the stresses on the cask, with 700 lbf/in^2 internal pressure during all drop orientations, will be under the allowable values, which closely follow the intent of the ASME pressure vessel design rules.[2]

The DYNA2D explicit finite element computer code [1] was modified to include the dynamic relaxation techniques used by Stone et al. [2]. The initial internal pressure was applied and an artificial damping factor of 0.3 per cent was used to damp out the initial transient dynamic response. A steady state solution for the internal pressure was achieved after running the analysis on a computer for about 3 ms real time; then the dynamic drop analyses were begun.

The results of these analyses show that combining the pressure with the dynamic impact loads did not significantly change the stress results in the sections where the stresses were already at yield during the dynamic events. As expected, for elastic stresses the pressure effect can be added by superposition.

In the hypothetical accident-condition 30 ft drop event, the drop energy is absorbed by plastic deformation of the impact limiters and portions of the containment boundary. The allowable stresses for the containment boundary are higher than yield stresses and are intended to prevent rupture. In addition, deformations in the area of the cask closure seals must be limited to prevent loss of seal integrity. Addition of pressure to the 30 ft drop event does not result in a significant change in the stresses of the critical sections or deformations in the seal area. The 30 ft bottom-end

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[1] 1 foot = 0.3048 m.

[2] 1 lbf/in^2 (g) = 6.895×10^3 Pa.

drop produces the highest stresses out of all the orientations evaluated. The effective stresses of the critical elements stressed beyond yield were increased by a maximum of 6 per cent for a 700 lbf/in^2 internal pressure. All the stresses in the cask were still below acceptable levels.

During the 1 ft normal-condition drop event, most of the stresses remain elastic. There are a few elements in the cask model which barely reach yield stress for a short duration. These stresses are increased slightly with pressure, but the total effective plastic strain in these sections is less than 0.58 per cent. This strain value is so small that the ability of the cask to absorb energy is not significantly reduced.

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