ANALYTICAL AND EMPIRICAL EVALUATION OF LOW-LEVEL WASTE DRUM RESPONSE TO ACCIDENT ENVIRONMENTS*

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INTRODUCTION

As part of an overall program to predict the response of low-level nuclear waste transportation systems to accident environments, Sandia National Laboratories (SNL) has been evaluating the structural response of 208 litre (55 gallon), 17C drums (Type A packagings), containing contact-handled transuranic waste (CH-TRU), to impact environments. Early analytical studies of entire transportation systems indicated that the Type A drum behavior had a strong effect on the systems' structural response. In addition, it is desirable to predict the failure of these drums as part of the overall assessment of package response in accident environments to serve as inputs to environmental impact statements. Finally, accurate definition of scale model drum response would allow less-expensive scale model tests to be performed during packaging development and assessment activities.

In order to assess the feasibility of simulating the drum response using existing computer codes, as well as to verify the adequacy of the subscale models, static and dynamic tests of full scale and subscale drums were conducted. This paper briefly describes the results of static and dynamic tests using full scale 17C drums and compares them to the results obtained from subscale tests and computer analyses of equivalent tests. More detailed information can be found in Ref. [1].

DESCRIPTION OF PROTOTYPE AND SUBSCALE DRUMS

Full scale drums actually used to package low-level waste were obtained from Rockwell International's Rocky Flats facility. The drum assembly consisted of a thin polyethylene bag (filled with waste) which was inside of a rigid polyethylene liner which in turn was contained by a 17C drum, Figure 1. The full scale drums were tested in four different configurations: filled with 90 kg of combustible waste, filled with either 225 kg or 320 kg of simulated sludge waste, or empty. The weights selected for the filled drums were representative of those shipped by Rocky Flats.

Scale model drums were simulated by using appropriately sized, commercially available, tinplated steel cans normally used for food packaging. Number 12 cans were used to simulate the 1/4 scale drums and #300 cans were used to simulate 1/8 scale drums. A comparison of the container sizes and thicknesses and the scaled prototype dimensions is shown in Table I. The diameters and heights compared

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within 3 percent, but the material thicknesses were 15 percent too small for the 1/4 scale cans and 16 percent too large for the 1/8 scale cans. The scale model drums were filled with material taken from previously tested prototype drums or with locally obtained material of similar composition. After the cans were filled to appropriate scaled weights (some cans were not filled), the lids were attached using a commercially available can sealer.

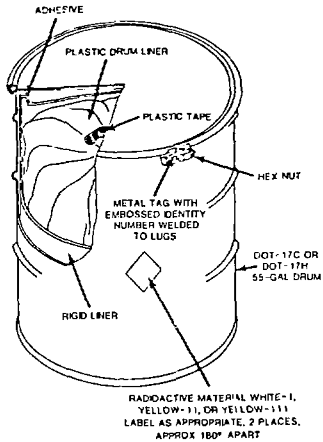

Figure 1. Typical 17C drum, Type A waste container with a rigid 2.5-mm-thick polyethylene liner

Table I
Dimensions and Comparisons of Prototype and Scale Model 17C Drums

CONTAINER	DIMENSIONS (mm)		
	Diameter	Height	Thickness
Prototype (17-C)	606	884	1.52
#12 Can	156	222	0.32
Scaled Prototype	152	221	0.38
#300 Can	75	113	0.22
Scaled Prototype	76	110	0.19

No attempt was made to model the polyethylene bag, rigid liner or the lid clamping ring since it was assumed that accurately modeling these details would not improve test results enough to justify the expense. The effects of neglecting these details are being investigated to verify this assumption.

STATIC TESTS

The first tests consisted of quasi-static crush tests of both full scale and subscale CH-TRU drums. This testing was undertaken in order to obtain the load-deflection behavior of the prototype containers for use in the computer analyses. Also by comparing the scaled prototype results to the load-deflection data for the subscale containers, an early estimate of the adequacy of the model containers was made. It was felt that if reasonable correlation was not found for the static tests, correlation between the same containers would not be possible in the dynamic tests, and a different model container would have to be obtained.

The full scale drums were tested in a universal testing machine which had 25-mm-thick steel plates attached to both the fixed and movable heads to assure adequate contact area during crush, Figure 2. Plots of crush force versus platen motion were generated from recording equipment attached to the testing machine. In addition, time lapse motion pictures were taken from two vantage points at the rate of one frame per second. The drums were crushed in a radial direction at a rate of 12.7 mm/min. The maximum crush of the drums was arbitrarily limited to one-half of the drum diameter, i.e., 305 mm. The scale model containers were tested in a similar manner except on a smaller capacity testing machine.

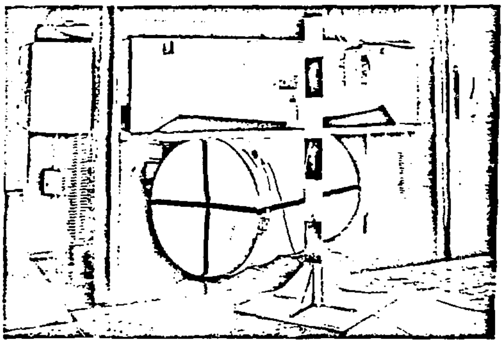

Figure 2. Static test configuration for prototype containers

Eight full scale drums were tested along with six 1/4 scale containers and ten 1/8 scale containers. The results of the prototype static crush tests show consistent load-deflection behavior, Figure 3. The initial crush phase and the occurrence of drum-lid separation can be seen to be independent of contents. The load-deflection plots show a sharp drop in load at about 64 mm (10% crush) which corresponds to the separation of the lid from the drum body. The contents and the amount of free volume did affect the later crush stiffness and the onset and severity of lockup. The behavior of the drums containing either 225 kg or 320 kg of simulated sludge was virtually identical, while the drums containing 90 kg of combustible waste appear to be slightly stiffer.

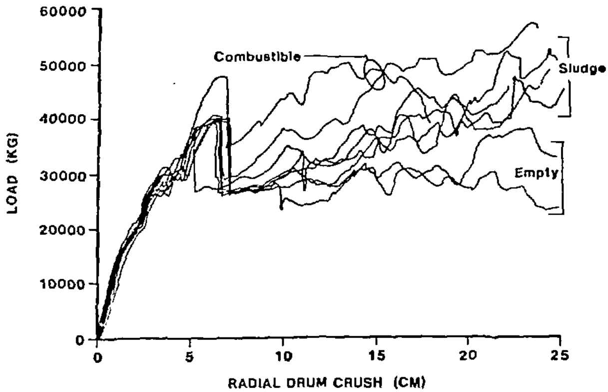

Figure 3. Comparison of the static load-deflection behavior of prototype drums - various contents

Figure 4 shows the results of the static tests of drums containing 225 kg of simulated waste. Results of equivalent scale model tests, appropriately scaled to prototype dimensions are also shown on the same figure. Good agreement between the prototype and 1/4 scale load-deflection behavior can be seen. The 1/8 scale behavior indicated that these models were approximately three times stronger than the prototype containers. This discrepancy was found to be caused by two factors: (1) the material in the scale models was stronger than the prototype material, and (2) the wall thickness in the 1/8 scale models was greater than the correctly scaled thickness. Neither scale model could duplicate the lid separation which occurred at 10% crush on the prototype drums because the prototype drums used clamping rings to secure the drum lids while the scale model container lids were rolled and crimped to the container body.

DYNAMIC TESTS

After the quasi-static prototype and subscale model tests had been completed, a series of dynamic tests was initiated. The objective of this test series was to obtain the characteristic deformed shapes and measurements for both the full scale and subscale Type A containers. Both single drum and multiple drum configurations were tested at impact velocities that might be encountered in a severe transportation accident. In some tests, a closed cell, rigid polyurethane foam, located between the container and the target, was used to simulate the impact mitigation properties of a typical transport container.

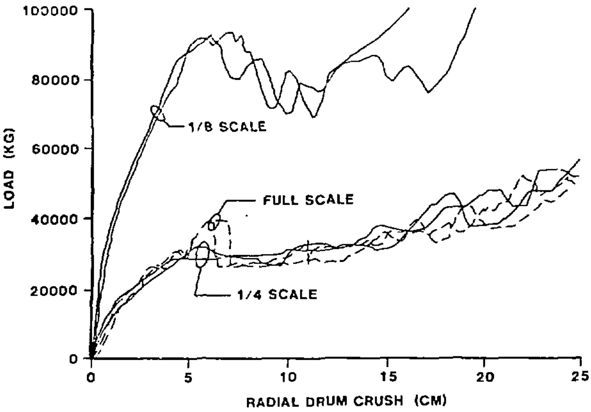

Figure 4. Comparison of the scaled load-deflection behavior for 1/8, 1/4, and full scale 225 kg containers

All dynamic tests were conducted at SNL's Coyote Canyon Drop Test Facility. The full scale drums were allowed to free-fall onto an unyielding target. It was determined that the smaller, scaled containers were subject to perturbations at release and during free-fall, therefore the scale model drums were guided into the target using a small diameter cable passing through guides attached to the cans. The target consisted of a 225 tonne concrete foundation topped by 10 cm of hardened steel plate. The multiple drum drops used a frame constructed of heavy angle stock to keep the drums in vertical alignment. No bulging or excessive deformations of the frames were observed during post-test inspections. Post-test measurements were made of the radial drum deformation, flattened impact area and, where applicable, foam deformation.

The results of the dynamic tests are consistent with the results of the static tests. Correlation was good between the prototype and 1/4 scale test results while the 1/8 scale results under-predicted the prototype deformations due to the greater stiffness. The deformed shapes of both models and prototype drums were generally in good agreement. Figure 5 shows a comparison of a prototype drum and the two subscale containers that impacted at 47 kph (29 mph). It was found that the addition of the polyurethane foam had little, if any, effect on the crush behavior of the multiple drum impacts.

Again separation of the drum lid could not be visually determined from the subscale models. However, after examining the full-scale and subscale static and dynamic test results, it was felt that lid separation in prototype tests could be predicted from scale model data. In both the static and dynamic tests, lid separation in the prototype drums occurred at approximately 10% crush. Therefore, a subscale drum which suffers a radial deformation at the lid of more than 10% infers that a full scale drum would open in the same test. This criterion can also be used to predict drum openings from the results of the computer simulations.

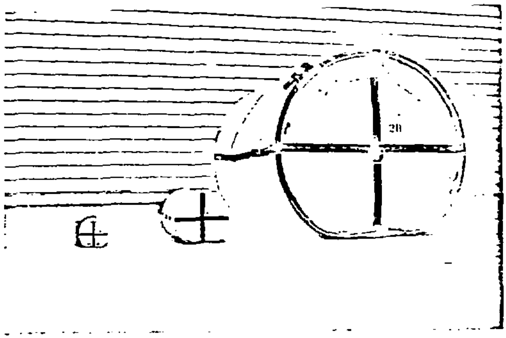

Figure 5. Post-test appearance of 1/8, 1/4, and full scale 320 kg containers following a 47 kph impact

ANALYTIC RESULTS

Two computer models were used to predict the response of an eight high array dropped from a height of either 6.4 or 9.0 meters. The first method used a lumped parameter code [2] to calculate the crush of each drum and the deformed array height. The drums were modeled in the code with a series of masses and springs which represented the weights and stiffnesses of the drums and the contents. The stiffnesses were obtained from the previously conducted static crush tests.

A finite element model using a SNL developed computer code [3] was also used. The drums were simply represented as solid cylinders of material. This representation required some average or equivalent material properties for the container system. The average material properties were determined from the previously conducted static crush tests. [1]

Both analytical models were able to predict the crush of an eight high array of drums with reasonable accuracy. Both models predicted the results for the maximum deflection of each drum, while in actuality the drums exhibit about 3.7 cm of springback. The results of both the lumped parameter model and the finite element model, corrected for the springback, are shown along with full scale and 1/4 scale test results for a 9.0 meter drop, Figure 6. The finite element model slightly over-predicts the crush of the top and the bottom two drums. This anomaly can be attributed to modeling the drums as a solid cylinder. The lumped parameter model gives a somewhat better prediction of drum crush, but with no indication of the deformed container shape. Both models give results which are within the expected repeatability of the tests. By using the previous criteria for lid separation, failure of the drum closure can be inferred at radial deformations greater than 6 cm (10%).

CONCLUSIONS

Based upon the results of the tests to date, it has been found that the structural response of low-level waste drums to impact environments can be generally predicted, both analytically and with subscale models. As currently represented, only the 1/4 scale models would adequately represent full scale drum deformation; however, additional work has shown that with proper heat treatingthe strength of the material used in the 1/8 scale containers can be reduced to the correct value. Both analytical models give results that are expected to be within the range of behavior of the full scale drums. Failure of the drum closure can be adequately inferred from the radial deformation results of both subscale tests and computer analyses.

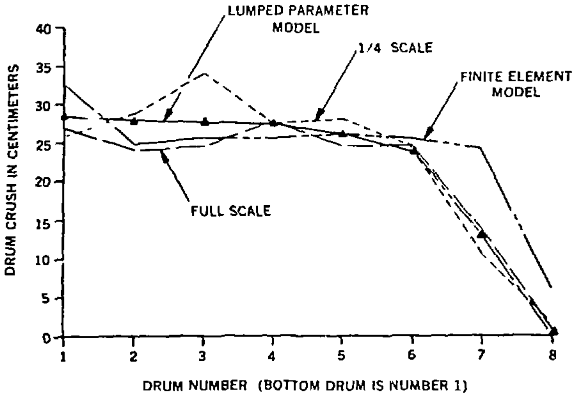

Figure 6. Comparison of full and 1/4 scale test results to analytical results; eight high stack, 9 m drop

REFERENCES

1. May, R. A., Romesberg, L. E., Lamoreaux, G. H., and Sutherland, S. H., "Analysis, Scale Modeling and Full Scale Tests of Low-Level Waste Drum Response to Accident Environments," SAND80-2517, Sandia National Laboratories, Albuquerque, NM, (to be published).

2. Gabrielson, V. K., and Reese, R. T., "SHOCK Code Users Manual, A Computer Code to Solve the Dynamic Response of Lumped-Mass Systems," Sandia National Laboratories, Livermore, California, Report No. SCL-DR-69-68, November 1969.

3. Key, S. W., "HONDO, a Finite Element Computer Program for the Large Deformation Dynamic Response of Axisymmetric Solids," Sandia National Laboratories, Albuquerque, New Mexico, Report No. SLA-79-0039, April 1974.