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Design and Testing of **MASTER** Wood Containers for Radioactive Waste

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Lawrence
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National
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DESIGN AND TESTING OF
WOOD CONTAINERS
FOR RADIOACTIVE WASTE

ABSTRACT

A wood container for shipping and storing radioactive waste was designed to eliminate the problems caused by the weight, cost, and shape of the steel containers previously used. Tests specified by federal regulations (compression, free-drop, penetration, and vibration) were conducted on two of the containers, one loaded to 2500 lb and one loaded to 5000 lb. The 5000-lb container failed the free-drop test, but the 2500-lb container easily passed the tests and therefore qualifies as a "Type A" container. Its simplicity of design, low weight, and ease in handling have proved to be time-saving and cost-effective.

INTRODUCTION

The Lawrence Livermore National Laboratory (LLNL), at the east end of the Livermore Valley in Alameda County, California, is a research institution operated for the Department of Energy by the University of California. The primary purposes of the Laboratory are nuclear weapons research and the development of alternate energy sources. During this research solid hazardous wastes, both radioactive and nonradioactive, are generated. The approximately 8000 cubic feet of radioactive waste sent for disposal each year must be handled, processed, packaged, and shipped according to EPA, DOT, and DOE specifications for "Type A" packaging. These requirements are documented under Title 49, "Transportation," of the *Code of Federal Regulations (CFR)*, paragraph 173.398, "Special Tests." The standards state that Type A packaging must be so designed and constructed that, if it were subject to certain environmental and test conditions,

- There would be no release of radioactive material from the package.
- The effectiveness of the package would not be substantially reduced.

- There would be no mixture of gases or vapors in the package which could, through any credible increase of pressure or an explosion, significantly reduce the effectiveness of the package.

The prescribed tests are:

- Compression: For packages of not more than 10,000 lb gross weight, the package shall withstand a compressive load equal to five times the weight of the package applied for a period of 24 hours (173.398(b)3v).

- Free drop: The package must withstand a free drop through a distance of 4 ft onto a flat, essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected (173.398(b)3ii).

- Penetration: The exposed surface of the package which is expected to be most vulnerable to puncture shall withstand the impact of the hemispherical end of a vertical steel cylinder, 1.25 in. in diam and weighing 13 lb, falling from a height of 40 in. (173.398(b)iv).

- Vibration: The container must withstand any vibration normally incident to transportation (173.398(b)2iv).

Environmental conditions are considered in the tests: heat (direct sunlight at ambient temperature of 130°F in still air), cold (ambient temperature of -40°F in still air and shade), and reduced pressure (ambient pressure of 0.5 atm).

These tests are intended to simulate accident conditions during highway transportation of hazardous material and static conditions during storage. Typical trucks for shipping the containers have 8-by-40-ft beds which are approximately 4 ft above the surface of the road. The drop test from 4 ft onto the container's weakest corner, striking an essentially unyielding surface, simulates the punishment that a container would receive if it were to fall from a truck during transportation.

The penetration test simulates impact by a projectile (internal or external), which a container might receive during sudden stops or other motions incident to transportation.

The compression test simulates the static load that a container must withstand if placed at the bottom of a stack of containers.

TABLE 1. Volumes, weights, and costs of containers for radioactive waste.

Container	Volume (m ³)	Empty weight (lb)	Maximum gross weight (lb)	Cost (\$)
Bennett Bucket	5.6	1400	7000	1500
Steel (4 × 4 × 7 ft)	3.2	2525	7000	2140
Wood (4 × 4 × 7 ft)	3.2	500	2500	400

An earlier container design, the Bennett Bucket, was a cylindrical steel tank 6 ft in diameter and 7 ft tall. All requirements for Type A packaging were considered in this design. It has been discontinued for reasons such as high cost and the fact that cylindrical containers do not stack efficiently for storage or disposal.

A rectangular steel container (4 × 4 × 7 ft) was also designed to fulfill Type A packaging requirements. This container is currently being used for special radioactive wastes, such as tritium, that must have containment impervious to gaseous diffusion. A problem in using steel is that the empty container contributes significantly to the gross weight of the load; this severely limits the weight of waste which can be packaged. The need remains for a practical, inexpensive, rectangular container.

We decided to design a wooden container; this report describes its performance when loaded to 2500 and 5000 lb. Its relative volume, empty weight, maximum gross weight, and cost are compared with those of the two previous container designs in Table 1.

CONTAINER CONSTRUCTION

The container is a wood box with outer dimensions of 4 × 4 × 7 ft; the construction design is shown in Fig. 1. The floor consists of five 2-by-8-in. grade A pine planks connected to three 4-by-4-in. Douglas fir runners with twelvepenny nails 3.25 in. long. The floor is covered with a sheet of 0.5-in.-thick A/B plywood fastened with 1.75-in.-long 15-gage staples (this size of staple is used throughout). The sides are of 0.75-in.-thick A/B plywood sheets fastened to a framework of 2-by-4-in. grade A pine with both

FIG. 1. Cutaway drawing of the wood waste container.

nails and staples. A stapling pattern of 6 in. is used. All joints except the floor planks and runners are glued with a special sealant adhesive. The lid is a 0.75-in.-thick plywood sheet glued, nailed, and stapled onto another 2-by-4-in. grade A pine framework. The sides of the box are reinforced by three 1.25-in.-wide steel bands tightened around the top and bottom edges and the middle. When the box has been filled the lid is glued into place and fastened with staples placed in pairs at intervals of 4-6 in. The box is painted inside and outside with a paint of a composition similar to that of the sealant and white in color, to help it withstand the temperatures it will be subjected to when stored in desert locations (the 2500-lb test container was not painted). The box is finally reinforced with four 0.75-in.-wide steel bands tightened around the box from top to bottom.

The ter-polymer sealant used in connecting the joints is a flexible emulsion-type blend of inorganic materials and acrylic polymers. This adhesive was chosen for its strength, superior adhesive properties (to 100 psi for porous surfaces), flexibility (elongation to 525%), and resistance to extremes of weathering and corrosives. A demonstration of the flexibility of the sealant is shown in Fig. 2. When all joints are sealed in this manner, the container's resistance to rigid-shock damage is greatly enhanced.

The simplicity of the construction design has the advantage that a large piece of contaminated equipment, for example, can be placed on the finished

FIG. 2. Flexibility of the ter-polymer sealant used in the wood waste container is demonstrated by radial flexing and folding.

floor of the container and the sides conveniently built around it. This eliminates the often awkward situation of lowering bulky and difficultly manipulated waste into a stable position within the container.

When a container is loaded it can be filled with a urethane foam, if necessary, to prevent shifting of the contents during transportation.

TESTS OF LOADED CONTAINERS

The materials loaded into the containers to be tested were chosen so as to reach the desired gross weight, completely fill the volume of the containers, and in the event of failure simulate the spilling of contaminated waste. A combination of Drysorb, Portland cement, and Microcel-E (diatomaceous earth) was used. The loading sequence for the containers is shown in Table 2.

The first of the two containers to be tested was loaded to a gross weight of 2500 lb. In practice the containers were to be limited to a maximum of that weight. The second container was loaded to a gross weight of 5000 lb,

TABLE 2. Materials used to load the test containers (in sequence).

Material	Amount	Total weight (lb)
Container loaded to 5000 lb gross weight:		
Dryorb	30 50-lb bags	1500
Cement	21 94-lb bags	1974
Dryorb	10 50-lb bags	500
Microcell-E	2 50-lb bags	100
Microcell-E	1 33-lb bag	33
Dryorb	8 50-lb bags	400
Empty container and lid		<u>500</u>
Total		5007
Container loaded to 2500 lb gross weight:		
Dryorb	30 50-lb bags	1500
Microcel-E	8 50-lb bags	400
Microcel-E	3 33-lb bags	99
Empty container and lid		<u>500</u>
Total		2499

which would be considered a worst-case situation because the container volume would not normally accommodate that much weight.

The compression, free-drop, and penetration tests (in that order) were run on each container; these tests were carried out at the Toxic Waste Control Group's facility at LLNL. The vibration test was run on the 2500-lb container by transporting it from LLNL to the Nevada Test Site (NTS).

COMPRESSION TEST

For the compression test, a 660-lb metal plate was first placed on the lid of each loaded container. The purpose of this plate was to contribute to a part of the total compressive weight (five times the total gross weight) and to distribute the weight uniformly across the top of the containers. The balance of the weight was made up by two pieces of steel armor plate for the

container loaded to 5000 lb, and by a loaded steel waste container for the container loaded to 2500 lb. The weights used for the compression tests are shown in Table 3.

The containers with the weights in place are shown in Figs. 3 and 4. For the duration of the compression test neither container showed any distortion or visible change in configuration.

TABLE 3. Weights used for compression test.

Item	Weight (lb)
Container loaded to 5000 lb gross weight:	
Metal plate	660
Armor plate (lower)	18540
Armor plate (upper)	<u>5960</u>
Total	25160
Container loaded to 2500 lb gross weight:	
Metal plate	660
Waste container	<u>12240</u>
Total	12900

FREE-DROP TEST

The free-drop test for the container loaded to 2500 lb was done in a high-bay facility with the use of an overhead crane. The crane is not rated to handle a load of 5000 lb, so that container was taken outside and elevated with a fork-lift truck.

Each of the loaded containers was elevated to a height of 4 ft and then released by means of a quick-release shackle. The containers were elevated in a position so that when dropped the impact would be on a corner where the lid is attached. (The top corner of a container, because of its construction design, is considered to be its most vulnerable point.) The containers were dropped onto a metal plate; the metal plate satisfies the condition that a container strike a flat, essentially unyielding surface.

FIG. 3. Container loaded to 2500 lb with weights in place for the compression test.

FIG. 4. Container loaded to 5000 lb with weights in place for the compression test.

The 5000-lb container is shown elevated in position above the metal plate in Fig. 5, and immediately after impact in Fig. 6. The plywood top ruptured, splintering and releasing a small amount of the Drysorb from inside. One of the four 0.75-in.-wide steel bands, near where the container ruptured, snapped upon impact; this probably contributed to the breaching of the container. The staples and the adhesive along the lid held; however, the plywood delaminated and the staples pulled through it yet remained imbedded in the side wall (see Fig. 7). One side of the container cracked on impact, creating a bulge, but the side held (see Fig. 8).

The container loaded to 2500 lb survived this test; it sustained some damage to a corner but maintained its integrity, as shown in Fig. 9.

FIG. 5. Container loaded to 5000 lb in position for the free-drop test, 4 ft above metal plate.

FIG. 6. Container loaded to 5000 lb lying on its top immediately after impact, showing rupture and spilled contents.

PENETRATION TEST

For the penetration test a rod was fabricated to meet the specifications set forth in 49CFR 173.398 (1.25-in. diam and weighing 13 lb). The apparatus for releasing the rod was a length of pipe drilled for the insertion of a pin at several different positions. This pipe was then attached to a stand on which it was elevated vertically above a surface of the container. The rod was then placed in the pipe with the hemispherical end pointed down, held in place at the desired height with the pin. For the test the pin was quickly removed by pulling on an attached wire, so the rod struck the surface of the container.

The apparatus for performing the test is shown in place, with the steel rod elevated to a height of 40 in. above the 5000-lb container, in Fig. 10. On

FIG. 7. Rupture of the 5000-lb container, showing delamination of the plywood and the staples having pulled through.

impact the rod produced a slight indentation about 0.12 in. deep and 1 in. in diam. As expected, the damage was slight.

VIBRATION TEST

Type A containers are transported by LLNL trucks or common carriers to NTS for burial. When the containers arrive and are ready to be unloaded and transferred to the burial pit, they are inspected for evidence of separation and cracking of the seams or other possible damage incident to transportation.

The requirements of Type A packaging regarding vibration were satisfied by observing the 2500-lb container after actual transportation in an exclusive-use vehicle to NTS, a distance of 635 mi. There was no visible effect of the vibration. No vibration test was run on the container loaded to 5000 lb gross weight.

FIG. 8. Bulge at crack
on side wall of the
5000-lb container.

FIG. 9. Damaged corner
of the 2500-lb container.

(After this container design was adopted, a representative shipment of 18 of the containers was sent to NTS; their weight range was 1411 to 3086 lb, with an average weight of 2012 lb and a median weight of 1818 lb. These containers also did not show any signs of damage resulting from vibration.)

ENVIRONMENTAL CONDITIONS

A temperature differential of 170°F , as specified in the requirements for Type A packaging, could cause some container materials to change configuration sufficiently to breach the integrity of the container, releasing radioactive material to the environment. However, the thermal expansion of the resin-bonded plywood used in our design is insignificant.

The thermal expansion coefficient for resin-bonded plywood is 4.2×10^{-6} per degree Fahrenheit.¹ This number represents the maximum measured expansion. For the 7-ft side of the container, expansion would be 0.06 in. over the temperature differential of 170°F . For the 4-ft side it would be 0.03 in. Considering the flexibility of plywood and of the ter-polymer sealant used to seal all of the container seams, this would cause no damage to the container.

For Douglas fir, the distortion at the center of the container wall due to a pressure differential of 0.5 atm would be²:

$$D_{\max} = \frac{0.1422wb^4}{Et^3(1 + 2.21\alpha^3)} = 4.8 \text{ in. ,}$$

where

$D_{\max}$ = maximum displacement

E = modulus of elasticity (1.95×10^6 lb/in.² for Douglas fir)

t = thickness in inches (0.75 in.)

w = load in lb/in.² (7.35 lb/in.²)

a = 84 in. (7 ft)

b = 48 in. (4 ft)

$\alpha = \frac{b}{a}$ (0.57)

This severe distortion would occur only under conditions such as the container's being taken to an altitude at which the ambient pressure is 0.5

FIG. 10. Steel rod in position for the penetration test, 40 in. above the top of the container.

atm (4.3 mi).³ A pressure differential on the walls of the container could also develop if a pressurized container such as a gas bottle or aerosol can inside the container were to rupture; however, these are not disposed of in wooden waste containers.

RESULTS

The results of the tests are summarized below.

Container loaded to 5000 lb gross weight:

Compression test: Passed; no visible effect on the container.
Free-drop test: Failed; slight release of the contents of the container (Drysorb).
Penetration test: Passed; very slight damage to the surface.
Vibration test: No vibration test was run on this container, since actual loading is limited to a maximum of 2500 lb.

Container loaded to 2500 lb gross weight:

Compression test: Passed; no visible effect on the container.
Free-drop test: Passed; minimal damage to a corner.
Penetration test: Passed; very slight damage to the surface.
Vibration test: Passed; no visible damage.

CONCLUSION

The container proved to be simple to assemble and can be built around bulky waste material. It is comparatively light, which increases the net payload, and the simplicity of the design and ease in handling have proved to be timesaving. The materials for construction are readily available and easy to work with. These features make the container cost-effective and practical. It easily meets Type A packaging specifications when limited to 2500 lb total gross weight. At 5000 lb the container performed well, but in our opinion did

not meet the criteria set forth in 49CFR paragraph 173.398(b)(1)(i): there could be a release of radioactive material from the package at a 5000-lb load.

This container has been adopted for Type A packaging of LLNL radioactive waste for transportation to NTS.

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