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ANALYSIS OF TYPE A PACKAGING SYSTEMS BASED ON GREATER THAN 400 INDIVIDUAL PACKAGING TESTS

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ABSTRACT

Type A packagings commonly used within the U. S. were studied to determine their performance with respect to, "Tests for demonstrating ability to withstand normal conditions of transport," (e.g., Water Spray, Free Drop (4 ft), Penetration, Corner Drop and Compression). There are several differences in U. S. and IAEA Type A packaging requirements and these are outlined in this paper. For purposes of this study, U. S. requirements were used. More than 100 separate packagings (>400 individual tests) were studied and evaluated. Most of these packagings can be divided into four basic groups: steel drums, wooden boxes, fiberboard containers, and steel boxes. This paper discusses: 1) "How did these systems perform?" and 2) "Suggested material usage and construction techniques."

The steel drums met all the requirements with a minimum of qualification and restrictions on use. The wooden boxes performed well, with three-way corner construction providing the best results. The Type A performance requirements had a much greater effect on fiberboard packagings (boxes and drums). In most cases penetration of the fiberboard container did occur, but this was dependent on the inner packagings and materials used.

Steel boxes offer a wide flexibility in types of construction, materials usable, volumes, and authorized gross weights. Material usage and construction for wooden and fiberboard containers, such as use of plywood in box construction, banding of boxes, and use of "firm" cushioning materials within fiberboard containers, are also discussed.

DISCLAIMER

1. INTRODUCTION

A study was conducted by Monsanto Research Corporation, Mound Laboratory, to determine how packagings commonly used within the U. S. for Type A quantities of radioactive materials performed with respect to "Tests for demonstrating ability to withstand normal conditions of transport." There are a few differences in the test requirements between the U. S. and IAEA[1] regulations concerning "normal conditions of transport." The U. S. test criteria were used in all of the tests; however, the differences and expected impact are discussed. These same packagings and styles of packaging are surely used throughout the world. In this study these questions were considered: 1) Just how well did the packagings perform? and 2) Do the test data support the use of specific materials and construction features of Type A packagings?

The general approach taken in this study was to divide the packagings (greater than 100 different packagings were tested, representing greater than 400 individual tests) into systems having basic similarities. The four systems which "naturally" fell out were: 1) Metal drums, 2) Wooden drums, 3) Fiberboard containers, and 4) Steel boxes.

The performance of each of these systems was evaluated with respect to five tests: 1) Water Spray, 2) Free Drop (4 ft) (1.2 m), 3) Corner Drop (1 ft) (0.3 m), 4) Penetration, and 5) Compression. The major differences in test requirements are:

Test	U. S. Requirement	IAEA Requirement
Water Spray	1) 1/2-hr duration.	1) 1-hr duration.
	2) Packages of (entire outer layer) metal, wood, ceramic, plastic and combinations thereof are exempt.	2) No exemptions listed; test is required preceding each of the free drop, compression, and penetration tests.
Free Drop	1) No change in requirements based on gross weight.	1) Drop distance reduced based on package gross weight.
	2) Corner drop (1 ft) (0.3 m) listed as separate test.	2) Corner drop incorporated as part of free drop test.
Corner Drop	1) Listed as separate test.	1) See item 2 (Free Drop).

[1]Regulations for the Safe Transport of Radioactive Materials-1973 Revised Edition, International Atomic Energy Agency (IAEA) Safety Series No. 6, Vienna.

Test	U. S. Requirement	IAEA Requirement
Penetration	U. S. and IAEA are essentially the same.	
Compression	U. S. and IAEA are essentially the same.	

The results of the study (certification of packagings as meeting Type A requirements) were documented [1] and distributed to U. S. Government agencies and to industry for use. Another document in preparation will provide pictorial results of the actual tests.

2. METAL DRUM SYSTEM

The basic characteristics of typical drums tested are given in Table I.

2.1 Metal Drum Test Results

2.1.1. Water Spray - This test is not required (U. S. regulations) and is not expected to have any significant effect.

2.1.2. Free Drop - As demonstrated in Fig. 1, each of the metal drums was dropped with the gross weight listed in Table I and although there were some instances of severe denting, in no case was there a loss of contents or significant reduction in packaging effectiveness.

2.1.3. Corner Drop - This test is not required by either set of regulations as long as package is not Fissile Class II.

2.1.4. Penetration - The damage ranged from severe denting (24 gauge) to very minor denting (18 gauge). These tests were conducted on both top and sides of these packagings.

2.1.5. Compression - There was no detectable effect with up to 4570 lb (2073 kg) on a 55-gal (208 ℓ) drum.

3. WOODEN BOX SYSTEMS

The basic characteristics of typical boxes tested are given in Table II and Fig. 2.

3.1. Wooden Box Test Results

3.1.1. Water Spray - This test is not required (U. S. regulations) and not expected to have any significant effect if applied (1/2 or 1 hr).

3.1.2. Free Drop (4 ft) - Figure 3 depicts typical results of the free drop test on the packagings in Table II. As is obvious the test at this specified gross weight had little effect. This is not to imply that all the boxes passed the first time they were tested.

TABLE I

Basic Characteristics of Typical Drums[a]

Volume	Body Thickness (Gage)	Top Thickness (Gage)	Authorized Gross Weight
5 gal (18.9 ℓ)	22 (0.76 mm)	22 (0.76 mm)	80 lb (36.3 kg)
5 gal (18.9 ℓ)	24 (0.61 mm)	24 (0.61 mm)	100 lb (45.4 kg)
10 gal (37.9 ℓ)	20 (0.91 mm)	20 (0.91 mm)	160 lb (72.6 kg)
30 gal (114 ℓ)	16 (1.52 mm)	16 (1.52 mm)	600 lb (272.7 kg)
30 gal (114 ℓ)	18 (1.21 mm)	18 (1.21 mm)	500 lb (226.8 kg)
55 gal (208 ℓ)	18 (1.21 mm)	18 (1.21 mm)	[b]
55 gal (208 ℓ)	18 (1.21 mm)	14 (1.90 mm) or 16 (1.52 mm)	840 lb (381.0 kg)

[a] All open-head drums.

[b] Two configurations with two different authorized gross weights; see page 23 of Reference 1.

TABLE II

Basic Characteristics

Type of Construction	Size	Authorized Gross Weight (kg)
1) 1.9-cm plywood, cleated ends, joints glued, sides nailed, and top screwed.	20 x 20 x 20 cm	20
	61 x 61 x 61 cm	152
	34(w) x 33(h) x 54 cm(l)	100
	13(w) x 13(h) x 51 cm(l)	21
2) 1.9-cm plywood, nailed joints and top	20 x 20 x 20 cm	19
	30.5 x 30.5 x 30.5 cm	45.5
	20(w) x 20(h) x 81 cm(l)	45.5
	10(w) x 10(h) x 41 cm(l)	9.5
3) 1.9-cm plywood, 3-way corner joints nailed and top screwed; cleats are pine.	30.5 x 30.5 x 30.5 cm	68
	61 x 61 x 61 cm	182
	20(w) x 20(h) x 81 cm(l)	66
	30.5(w) x 30.5(h) x 122 cm(l)	114
4) 1.9-cm plywood, corner post construction; joints and top nailed	30.5 x 30.5 x 30.5 cm	68
	61 x 61 x 61 cm	68
	20(w) x 20(h) x 81 cm(l)	68
	30.5(w) x 30.5(h) x 61 cm(l)	68

In many cases, greater gross weights were tested and the boxes were determined to "fail" the test. An example of a typical failure is shown in Fig. 4.

3.1.3. Corner Drop - This test is required only for boxes not exceeding 50 kg, and this test had little effect on the overall containment integrity, independent of the type of construction.

3.1.4. Penetration - There was no significant effect when materials of construction exceeded 1.3 cm of plywood; however, the bar did penetrate 0.64-cm plywood and did result in cracking of such woods as 1.3-cm pine.

3.1.5. Compression - There were no detectable effects with up to 2500 lb (1136 kg) applied for 24 hr.

4. FIBERBOARD CONTAINER (BOX AND DRUM) SYSTEMS

The basic characteristics of fiberboard container systems are given in Tables III and IV.

4.1 Fiberboard Boxes Test Results

4.1.1. Water Spray (1.2 hr) - This test did not have any significant effect by itself; however, it probably did significantly change the response of the fiberboard packaging to the free drop (4 ft) test.

4.1.2. Free Drop (4 ft) - This test was in all cases preceded by the water spray and in several cases resulted in "minor" breaches of the box. The boxes tested were all "authorized" for 29.5 kg; however, not all the boxes passed at that weight, hence, the actual authorized gross weights listed in Table III. An example of a failure at 29.5 kg is shown in Fig. 5.

4.1.3. Corner Drop - This test was conducted in two different manners, sometimes on packagings which had been subjected to the water spray and free drop (4 ft) and at times on packagings which had not been given these two tests. In either case the corner drop test did not seem to have a significant effect on the overall containment integrity of the boxes.

4.1.4. Penetration - In most cases the bar penetrated the top, and in practically all cases the bar penetrated the sides of the box. This led to qualifications placed on the inner containment and/or packaging materials. [2] Rubberized hair was the packaging material used in the boxes which were penetrated. It should be noted that a similar box (authorized for 29.5 kg) with a polyfoam insert consistently passed the penetration test on the side. The performance with respect to the penetration test then is dependent on the internal packaging materials which are used.

4.1.5. Compression - This test was not preceded by the water spray test, and the results depend on the weight required - 5 times gross

TABLE III

Basic Characteristics of Fiberboard Containers

Exterior Dimensions (Assembled and Sealed) of Fiberboard Box Sizes Tested						Authorized Gross Weight	
Width		Height		Length			
(in.)	(cm)	(in.)	(cm)	(in.)	(cm)	(lb)	(kg)
12.5	31.8	12.5	31.8	9.5	24	26	12
12.5	31.8	12.5	31.8	13	33	26	12
14.5	36.8	17.5	44.5	28.5	72.4	65	29.5
18.5	47.0	13.5	34.3	18.5	47.5	41	18.5
18.5	47.0	18.5	47.0	19	48.3	65	29.5
24.5	62.2	24.5	62.2	24.5	62.2	65	29.5
24.5	62.2	12.5	31.8	24.5	62.2	65	29.5

TABLE IV

Size of Fiberboard Drums Tested

Volume		Outside Height		Authorized Gross Weight	
(ℓ)	(gal)	(cm)	(in.)	(kg)	(lb)
76	20	62	24	52	115
57	15	47	18	27	60
57	15	47	18	27	60
114	30	66	26	52	115
114	30	66	26	52	115
208	55	88	34	182	400

weight (29.5 kg) or 1300 kg/m^2. In all cases, the packagings passed the 5 times the gross weight without major deformation or compression. However, the packages with larger top surface areas required up to 550 kg. Weights such as this did in some, not all, cases result in severe distortion. Based on these data, qualifications were applied to the stacking of these packagings.

4.2 Fiberboard Drums Test Results

4.2.1. Water Spray - This test did not have any significant effect by itself; however, it undoubtedly had an effect on the results of the free drop.

4.2.2. Free Drop (4 ft) - This test was in all cases preceded by the water spray test. Seven different drums were tested and one did fail (Fig. 6). Additional qualification of this test may be required, since recent testing has indicated that the bottom of these packagings may be the most vulnerable area. This is currently being pursued.

4.2.3. Corner Drop - This test was required only for drums not exceeding 50 kg (U. S. regulations) and had little effect on the packaging integrity.

4.2.4. Penetration - All but one of the six drums tested had metal covers [24-28 gauge (0.61 mm-0.38 mm)], and the bar did not penetrate the covers in any instance. The results on sides and bottoms were not consistent. Similar tests gave varying results from minor identations to cracks, tears, and outright penetration. In view of these results, a qualification was placed on the use of this packaging. [1]

4.2.5. Compression - As shown in Fig. 7, a compressive load of five times the gross weight (max. of 909 kg) was placed on these packagings and in all cases there was no significant compression or effect.

5. STEEL BOXES

The basic characteristics of steel boxes are given in Fig. 8-10.

5.1. Steel Box Test Results

5.1.1. Water Spray - This test is not required (U. S. regulation) for steel boxes and was not expected to have any significant effect if applied (1/2 or 1 hr).

5.1.2. Free Drop (4 ft) - There was no detectable effect of the free drop (4 ft) test on the box shown in Fig. 10. This box had a gross weight of approximately 909 kg. After the 4-ft drop, the same

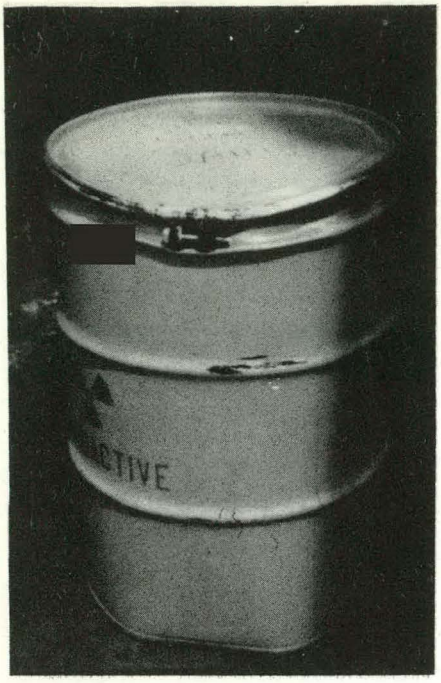

FIG. 1 Results of free drop (4 ft) of 17H 55-gal drum with gross weight of 840 lb; major dents top and bottom, but no loss of contents.

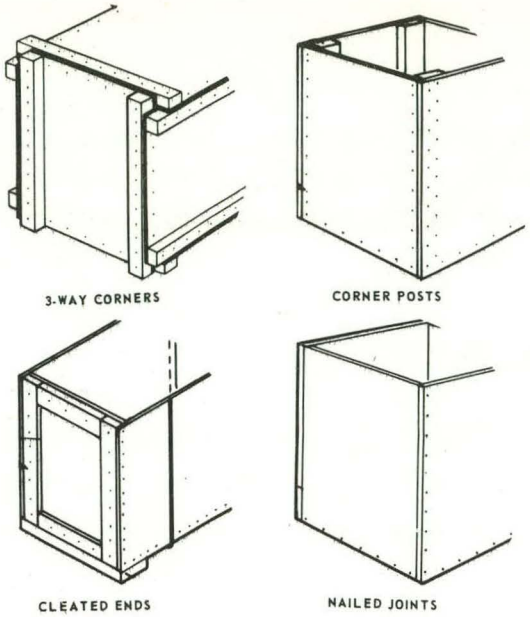

FIG. 2 Plywood box constructions.

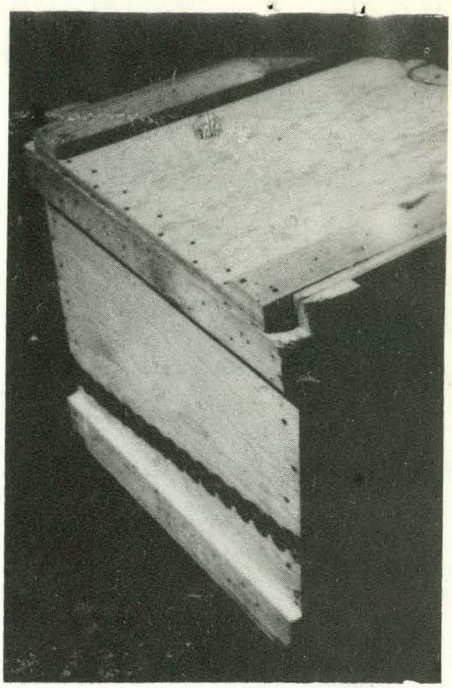

FIG. 3 Results of free drop (4 ft) test on box with gross weight of 400 lb; a minor scuffing of the corner.

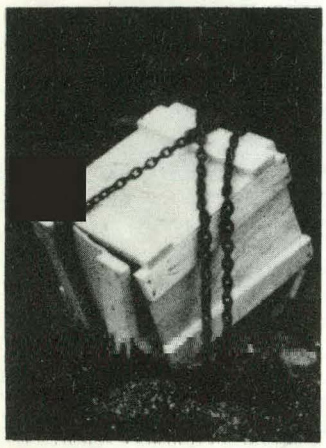

FIG. 4 Results of free drop (4 ft) of 19A wooden box (3-way corners, ⅛ in. plywood, pine cleats, and gross weight of 400 lb). It appeared that the only thing holding the box together was the chain used in dropping the packaging.

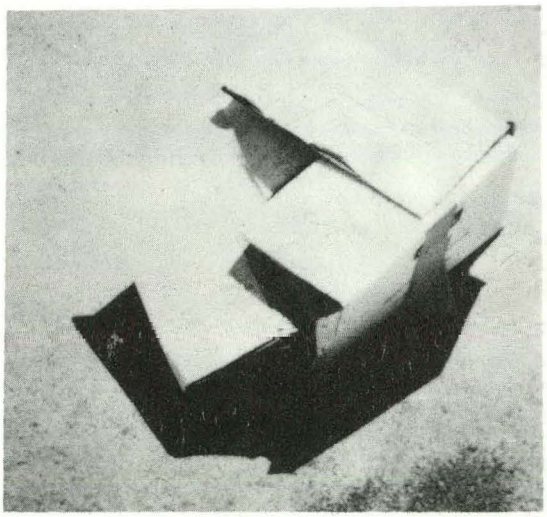

FIG. 5 Results of free drop test following ½ hr water spray test; complete collapse of the box; gross weight 65 lb.

FIG. 6 Result of free drop after ½ hr water spray of 21C drum (115 lb authorized gross weight); loss of contents.

FIG. 7 Compressive load of 2000 lb applied for 24 hr: no effect. The plastic bag was put over the drum because of threatening rain.

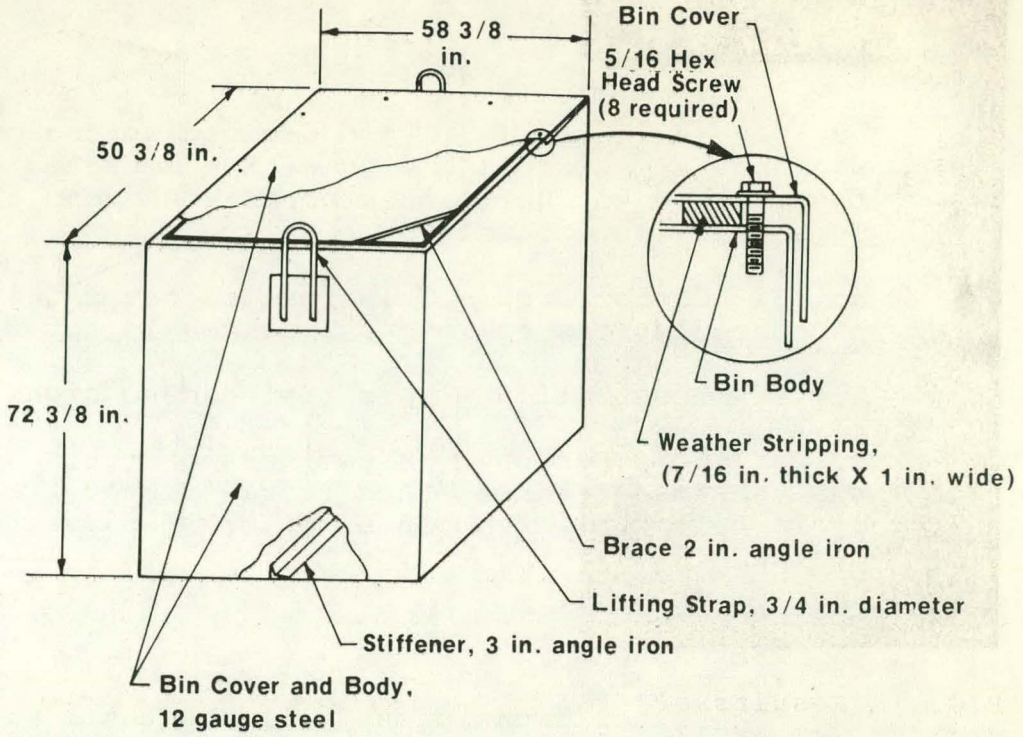

FIG. 8 Construction of DOT Spec. 7A steel box with authorized gross weight of 1455 kg.

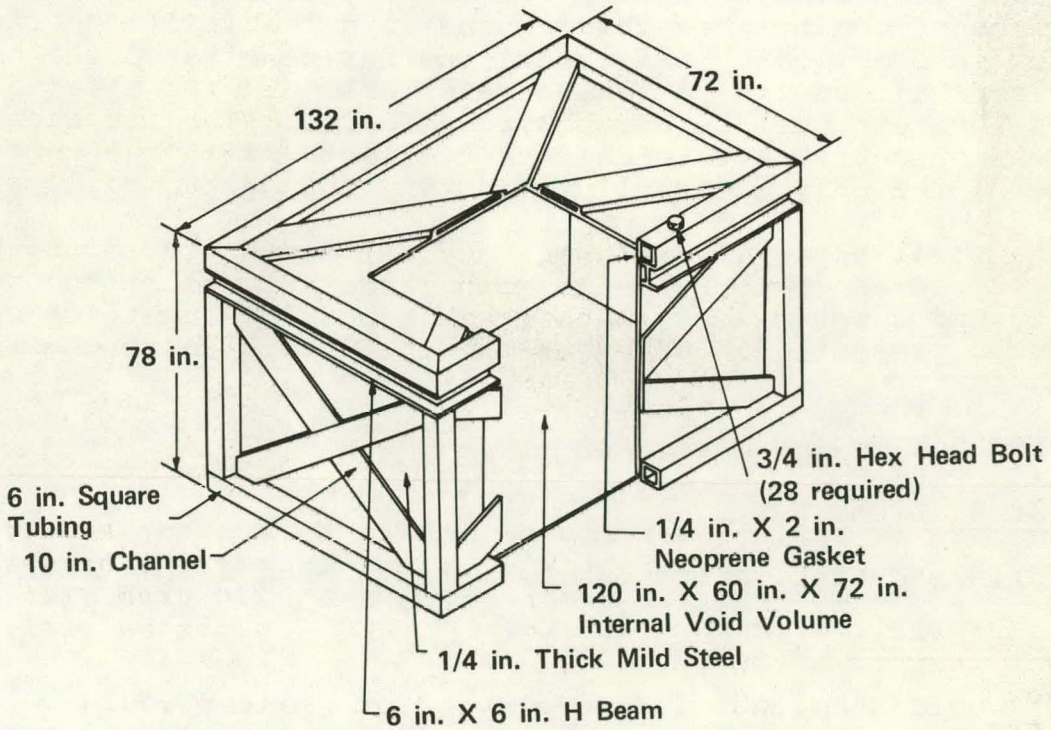

FIG. 9 Construction of DOT Spec. 7A steel box with authorized gross weight of 5909 kg.

box was raised to 10 ft and dropped on the opposite end. There was a barely visible bowing of the impacted edge. The same box was then raised to 30 ft and dropped; the result was an 8-in. (20.3-cm) long crack in one weld.

5.1.3. Corner Drop - This test is not required by either U. S. or IAEA regulations as long as package is not Fissile Class II.

5.1.4. Penetration - This test had no significant effect.

5.1.5. Compression - No compression tests were conducted or analyses made; hence, each is restricted from stacking. However, it is felt that each container would pass the test if it were conducted.

6. PERFORMANCE

The steel drums passed all the tests with a minimum of qualifications or restrictions imposed.

The wooden box systems exhibited a high degree of integrity; however, there were "failures" during the free drop (4 ft) test at what was considered moderate gross weights; that is, the boxes did not behave quite as well as expected. As stated previously 0.64-cm plywood failed the penetration test as shown in Fig. 11.

The fiberboard boxes were significantly affected by each individual test (excluding the water spray test by itself). In several cases a minor breach occurred as a result of the free drop (4 ft). In practically all cases, the bar penetrated the box (with rubberized hair as the packaging material), and the effects of the compression test must be strongly considered. The fiberboard drums were less susceptible to significant effects, with the penetration test being the only one really affecting the packaging.

The steel boxes (3 different styles) demonstrated that a wide variety of boxes could be built with large net volume and weight capacity which would meet (with certain possible restrictions such as reduced pressure and compression) the Type A requirements.

7. CONSTRUCTION AND MATERIALS

7.1. Steel Drums

Again the steel drums demonstrated a high degree of integrity.

7.2. Wood Boxes

It would seem that 1.3-cm plywood or greater would be generally advisable (although not a requirement by any means) and steel (and even nylon tape) banding was shown to be a very beneficial construction feature for box type packagings and is commonly used within the U. S. The use of woods such as pine (up to 2.5 cm) rather than

plywood is questionable based on cracking occurring during the penetration test. There are not enough data to analyze screw vs. nailed construction, although it seemed that there were fewer seam separations, etc., with screw closures. One item to consider for long, thin wooden boxes is the secondary impact encountered during the corner drop. In one series of tests conducted on such a packaging, the actual corner impact seemed to have little effect, but the secondary impact of the 10-ft box falling to the ground eight times had a major effect on the packaging. In general, additional inner packagings would be used within a wooden box for dispersible radioactive materials. Fixing the position of heavy contents within packagings is important. There were several examples of the "ram" effect producing packaging failures during these tests.

7.3. Fiberboard Boxes

Fiberboard boxes (authorized gross weights of 29.5 kg and 8.2 kg) were tested and were (dependent on internal packaging materials) penetrated by the bar. In constructing a fiberboard box package, one must either use an inner container resistant to the penetration test or use cushioning to ensure that contact/significant effect between the bar and inner container does not result. The type of tape used to seal the box is also important. Nonreinforced 10.2-cm wide plastic tape was used in these tests and was a strong contributor to packaging integrity (e.g., resistant to penetration test and added significant structural strength when used as a banding). Steel bandings when used also provided noticeable strength to the packaging. The fixing of heavy contents within the box is important.

7.4. Fiberboard Drums

Fiberboard drums with and without surface preparation (water resistance) were tested and no significant differences (based on these few tests) were noted.

7.5. Steel Boxes

Steel boxes seem to be flexible in use and construction style which meet the Type A packaging requirements.

8. SUMMARY

In general, the packagings tested exhibited a high degree of integrity; however, in several instances (some wooden boxes, fiberboard boxes, and fiberboard drums) as a result of the tests conducted the authorized gross weights were reduced from previously authorized gross weights. The construction methods and materials used are sound and sturdy, although there are several suggestions for enhancing the performance of the packages.

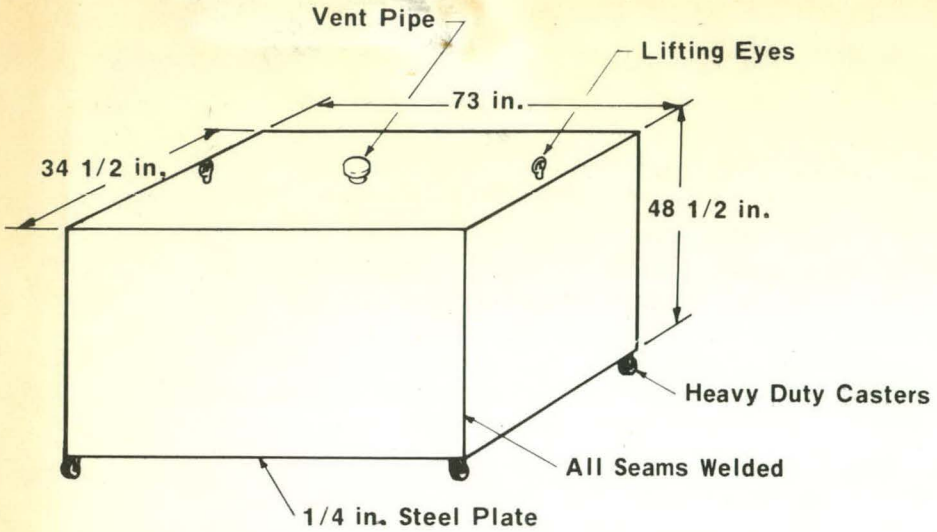

FIG. 10 Construction of DOT Spec. 7A steel box with authorized gross weight of 2273 kg.

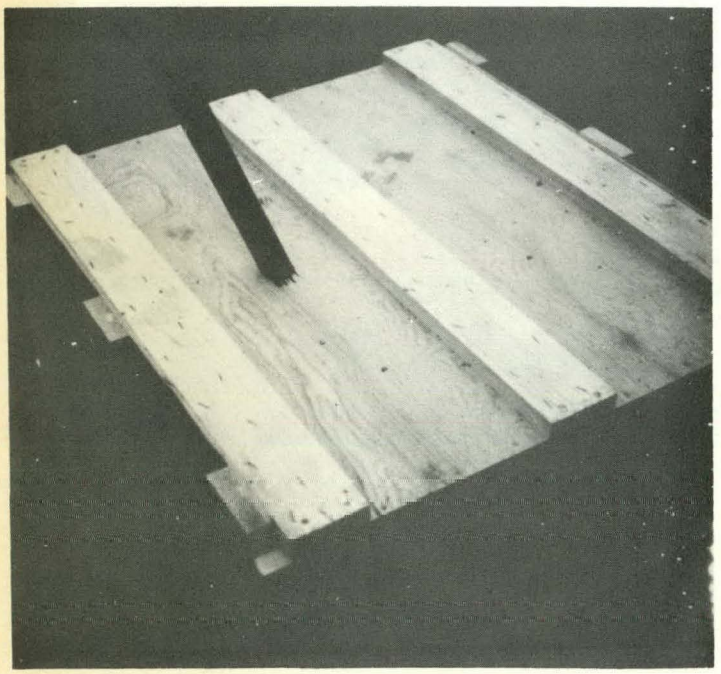

FIG. 11 Result of penetration test; bar penetrated the ¼-in. (0.64-cm) plywood.

9. REFERENCES

[1] EDLING, D. A., Griffin, J. F., Certification of ERDA Contractors' Packaging with Respect to Compliance with DOT Specification 7A Performance Requirements - Phase II Summary Report, USERDA Rep. MLM-2228 (1975).

[2] EDLING, D. A., GRIFFIN, J. F., Certification of ERDA Contractors' Packaging with Respect to Compliance with DOT Specification 7A Performance Requirements - Phase II Summary Report (Supplement No. 1), USERDA Rep. MLM-2228 (1976).