Leak Tests by High-Velocity Impact of Infectious Specimen Containers

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SPECIFIC REQUIREMENTS for packaging containers of infectious diagnostic specimens for international mail are stated in U.S. Postal Manual section 221.325 c.(2) as follows: "Perishable biological material of a pathogenic nature must be packed in a tightly closed bottle or tube of heavy glass wrapped in thick absorbent material rolled several times around the bottle or tube and tied at the ends, sufficient in quantity to absorb all the liquid; the wrapped container must be placed in a strong well-closed metal box constructed to prevent any contamination outside of it. This metal box must be wrapped in cushioning material and placed in an outer protective box where it should fit tightly to avoid shifting. The outer container must consist of a hollow block of strong wood, metal, or other equally strong material with a tight lid so fitted that it cannot open during transportation." The requirements for domestic mail, parts 124 and 125, are less detailed.

Shipment of infectious material in the amount defined for a diagnostic specimen is exempt, however, from requirements in the Code of Federal Regulations (CFR) 42:72.25. These requirements specify placement of the specimen in a watertight, airtight container, with sufficient surrounding absorbent material to absorb the entire contents, a second durable watertight, airtight container, and a third individual shipping container of corrugated cardboard fiber or material of equivalent strength. One gallon of contents in the container is the limit for shipment.

An interesting aspect of these specifications is that none includes a test standard for determining how much rough handling the containers will withstand. In a 1960 report, Kokko and associates (*1*) described the results of drop-testing various specimen containers 20 feet to concrete and 1,000 to 1,500 feet to hard sun-baked ground. Containers also were subjected to 3,000 pounds vertical pressure, 800 to 1,200 pounds horizontal pressure, and explosive decompression to 1.69 pounds per square inch in 0.1 second. The investigators used glass serum bottles, glass test tubes, and glass milk dilution bottles, surrounded by absorbent material, in a crimp-sealed or friction-sealed tin can that was packed in an outer cardboard container. During the tests a few glass tubes or bottles broke, but there was no leakage through the outermost (third) container.

Other types of packages used for transmitting containers of diagnostic infectious specimens through postal mail are described in table 1. Packages I and P complied with the postal regulation requiring absorbent cotton around the test tubes, but the tin (second) container could not be wrapped in cotton because of the lack of space between it and the outer

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fiber cylinder. Package F, containing a 10-milliliter glass test tube had enough cotton packing to absorb the contents, but neither the tube nor the tin container could be wrapped in cotton because of the small spaces between the test tube and the tin and outer fiber containers. All tubes were wrapped in such a way as to avoid glass-to-glass contact.

The purpose of our experiment was to leak-test containers of diagnostic specimens at impact velocities approaching those they might experience as a result of accidental jettison from an aircraft or on impact within the aircraft during a crash takeoff or landing. Such testing required the establishment of an impact velocity that might be sustained by a package during a crash. The velocity selected as a test standard was 145 to 165 feet per second (106 miles per hour ± 6.5 percent).

The test figure was obtained by studying the net effect on the aluminum honeycomb shock absorber in the forward end of a large package placed in a cargo aircraft that was experimentally crashed at 138 miles per hour, under controlled and mechanically recorded conditions, into a reinforced concrete wall. This experiment was part of an Air Force project during which calculation of the net velocity impact of the package was of special value to Public Health Service personnel interested in introducing a container performance test standard into CFR 42:72.25.

Naturally, there is a tremendous range of variable impact speeds and conditions to which packages of different weights and shapes would be subject during the crash of an aircraft, so we used the standard velocity of 145 to 165 feet per second, knowing that it represented only an order of magnitude. Although the maximum velocity achieved in our tests was 139 feet per second, it was enough to show the extent of damage that could occur at an impact of 145 to 165 feet per second.

Materials and Methods

Impact conditions. Three weights and sizes of packaged containers of diagnostic infectious fluid specimens were impacted on reinforced concrete by the device shown in figure 1. The speed of impact was measured by a model 5233L Hewlett-Packard electronic counter (table 2). The packages were fired a distance of 72⅜ inches from the end of the barrel to the concrete pad.

The average impact velocity was 130 to 133 feet per second, but attainment of this velocity in 6 feet means that the initial acceleration was almost as violent as the impact. Therefore, the

Table 1. Description of tested packaged containers

Package identification	Primary container	Packing	Secondary container	Packing	Outer (3d) container	Average weight of package (oz.)
F14–F23	1 pyrex glass test tube, plastic screw cap with liner, 6 inches long by ¾ inch outside diameter.	Absorbent cotton, top and bottom.	Metal can, screw top, 7 inches long by 1 inch outside diameter.	Small amount of absorbent cotton, tight fit.	Fiber body, metal screw cap, metal top and bottom, 7⅛ inches long by 1½ inches outside diameter.	4. 22
I15–I24	4 test tubes, as described in F.	Absorbent cotton all around tubes.	Metal can, screw top, 6⅝ inches long by 2¾ inches outside diameter.	do	Fiber body, metal screw cap, metal top and bottom, 7⅝ inches long by 3½ inches outside diameter.	16. 15
P1–P10	2 test tubes, as described in F.	do	do	do	do	14. 15

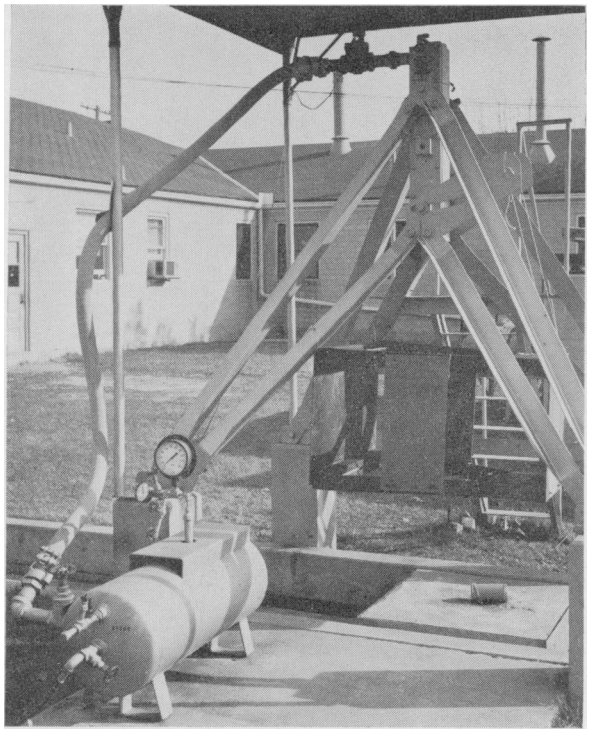

Figure 1. Firing device used for high-velocity impact tests of packaged containers onto concrete

test was more severe than if a drop-test or gradual acceleration had been used. All the packages were alternately oriented so that five impacted on the bottom and five on the top. Sabots were made for the packages to adapt them to the diameter of the firing tube.

Description of packages. The three basic types of packages are described in table 1; 10 replicates of each type were prepared for testing. Each test tube in the packages contained 10 milliliters of 0.2 percent safranin dye.

Results

The results of our tests are summarized in table 2.

F packages. Figure 2 shows the condition of the F packages, containing one test tube each, after impact at an average velocity of 130.2 feet per second (88.77 miles per hour). Figure 3 shows a typical package disassembled after impact. In all except one F package, the small amount of cotton at the top and bottom of the secondary metal container absorbed the 10 milliliters of liquid dye; in one package, the cotton was saturated and a spot of dye appeared on the outer fiber container. None of the liquid leaked through the outer container.

I packages. The condition of the I packages, containing four test tubes each, after impact at 132.8 feet per second (90.54 miles per hour) is shown in figure 4. All the tubes were broken. In several tests the screw caps on one or two tubes were cracked (table 2), but little or none of the contents leaked onto the absorbent cotton. Figure 5 shows a typical package disassembled after impact. None of the dye leaked through the outer fiber container.

P packages. The external and the internal

Table 2. Impact velocities and resulting condition of test tubes

Tube No.	Velocity [1] (fps) [2]	Air (psig) [2]	Tubes intact
F14	128	104	0
F15	132	102	0
F16	134	105	0
F17	[3] 130	102	0
F18	136	98	0
F19	120	98	0
F20	134	98	0
F21	125	100	0
F22	137	100	0
F23	126	102	0
I15	136	100	0
I16	[4] 337	102	[5] 1
I17	127	105	0
I18	136	105	0
I19	127	105	0
I20	136	89	[5] 1 and 3
I21	139	102	0
I22	128	105	[5] 2
I23	130	102	0
I24	136	104	[5] 1
P1	133	105	0
P2	128	104	0
P3	134	104	0
P4	127	105	0
P5	128	102	0
P6	133	104	0
P7	133	104	0
P8	131	104	0
P9	131	102	0
P10	130	102	0

[1] F average, 130.2 fps (88.77 mph); I average, 132.8 fps (90.54 mph); and P average, 130.8 fps (89.18 mph).

[2] fps=feet per second; psig=pounds per square inch gauge.

[3] Estimate.

[4] The electronic counter used to count the time lapse between two photoelectric light sources either malfunctioned in counting or the numbers were not canceled before the next test. A conversion factor was introduced to calculate the feet per second (velocity).

[5] Tube intact but cap broken.

condition of the P packages after impact at 130.8 feet per second (89.18 miles per hour) was the same as for the I packages (figs. 4 and 5). All the dye was absorbed by the cotton; none leaked through the outer fiber container.

Summary

The Department of the Army performed leak tests on three weights and sizes of commonly used packages, consisting of containers of diagnostic infectious specimens, by impacting the packages on reinforced concrete. The three types of packages complied with the requirements for domestic mail set forth in the U.S. Postal Manual, parts 124 and 125. They complied only in part, however, with the specifications in section 221.325 c.(2) pertaining to international mail although they met the intent of the regulation, which is to insure the absence of leakage during transport.

One test package consisted of a single glass test tube holding 10 milliliters of 0.2 percent safranin placed inside a metal container, with cotton packing at the top and bottom, and an outer fiber cylinder, 7 5/16 inches in length and 1½ inches in diameter, with a small amount of cotton packing inside at its top and bottom.

The second package contained two glass test tubes and the third contained four glass test tubes. A single length of cotton was wrapped around the tubes in such a way as to avoid glass-to-glass contact before they were inserted into the metal container and the outer fiber cylinder. The outer cylinders in the second and third packages were 7⅝ inches in length by 3½ inches in diameter.

None of the three packages leaked when impacted on concrete at average velocities of 130 to 133 feet per second (89 to 90 miles per hour). The mailing tubes more than met the requirements for no leakage under conditions ordinarily incident to handling during transportation.

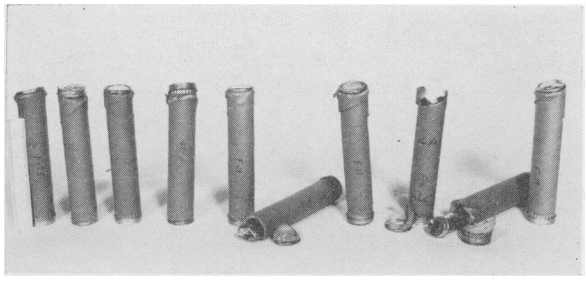

Figure 2. Condition of F packages, containing a single tube each, after impact

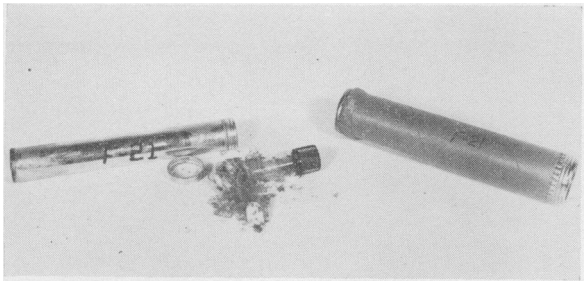

Figure 3. Condition of single tube in F package after impact

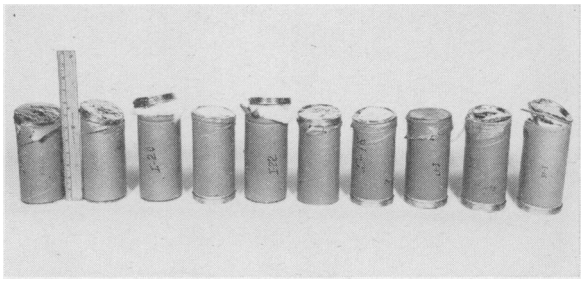

Figure 4. Condition of I packages, containing four tubes each, after impact

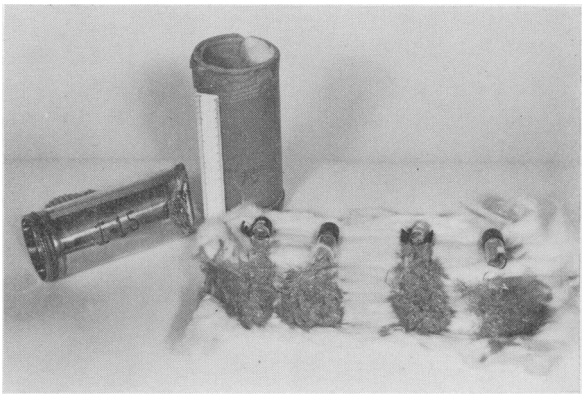

Figure 5. Condition of four tubes in I package after impact

REFERENCE

(1) Kokko, U. P., Stuart, J., and Taylor, G.: Mailing of infectious specimens for diagnostic purposes. Public Health Rep. 75: 979–984, November 1960.