Laboratory and Service Tests of Hand Luggage

United States Department of Commerce

National Bureau of Standards

Miscellaneous Publication 193

UNITED STATES DEPARTMENT OF COMMERCE • Charles Sawyer, *Secretary*
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by Edward T. Steiner, Robert B. Hobbs, and Elizabeth R. Hosterman

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Issued July 1, 1949

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 15 cents

PREFACE

The durability of hand luggage is often a matter of serious concern for nearly every traveler, as well as for manufacturers and distributors of luggage and for the transportation industries. Yet when representatives of the railroads, busses, and air lines asked the National Bureau of Standards for assistance in preparing a commercial standard for this commodity, it was found that there existed practically no reported research on the subject. For this reason the Bureau conducted a survey of luggage in service, in bus and railroad stations in 10 cities, to get information needed in developing performance tests for hand luggage.

The findings of the surveys, showing the materials and types of luggage occurring most frequently, the general condition of luggage in service, and the loaded weights of bags in service, are presented in this report. The three laboratory performance tests suggested by the authors require only rather simple apparatus and yield results of adequate precision. These tests have been shown to correlate well with the behavior of luggage in actual service, and therefore seem suitable for use in a commercial standard.

E. U. Condon, *Director.*

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Test methods for hand luggage are suggested as suitable for inclusion in a commercial standard for this commodity. The methods are based on laboratory and service tests of hand luggage, which are reported in detail. The materials and types of bags studied were chosen in accordance with the results of surveys in rail and bus baggage rooms. The results of the surveys, showing the types and materials of construction occurring most frequently, the general condition of luggage, and the loaded weights of bags in service, are presented. The relationship of properties of luggage to the kind and extent of damage occurring in service is discussed.

The three test methods recommended are: A static load test, a handle fatigue test, and a repeated drop test. Minimum performance requirements for these tests are suggested. The results obtained from these methods correlated well with the behavior of replicate pieces of luggage in service. Two other methods, a puncture test and the hexagonal revolving drum test, showed promise, but are not recommended at this time, because the results are insufficient to justify the high cost of the apparatus.

I. Purpose and Plan of the Investigation

This study of hand luggage was undertaken for the purpose of developing test methods suitable for inclusion in a Commercial Standard for hand luggage, and in order to obtain data sufficient to establish minimum performance requirements for such a standard.

A commercial standard is a recorded voluntary standard of a trade and covers such items as types, grades, and use characteristics. Their method of establishment is described in a leaflet.[1] The initial request for a commodity standard for luggage came from the American Association of Baggage Traffic Managers, and was soon supported by similar requests from the National Bus Traffic Association and the Air Traffic Conference of America. It soon became evident, however, that the available data on tests and properties of hand luggage were insufficient to serve as a basis for a commodity standard, and the National Bureau of Standards was therefore requested to conduct this investigation to develop the necessary technical information.

The annual loss and damage to hand luggage are large, but data are not available to permit an accurate estimate of the amount. Loss and damage claims paid for luggage in the hands of common carriers total about $1,250,000 annually, according to statistics from the Interstate Commerce Commission and from certain air lines. This figure does not reflect loss and damage to luggage in the hands of owners, or for which no claims are entered, nor does it take account of the incidental inconvenience to travelers or the cost to carriers of processing claims.

The experiences of common carriers, confirmed by observations in baggage rooms during this investigation, indicate that a major proportion of the annual loss and damage is caused by the use of luggage that either was not intended by the manufacturer for ordinary baggage service, or which has easily remediable defects in materials or construction.

The general plan of this investigation involved three principal steps: First, a survey of luggage in actual service to determine pertinent facts about its treatment; second, the development of laboratory tests, which, in a short time, would reproduce qualitatively and quantitatively the kind of damage occurring in service; and third, the correlation of results of such laboratory tests with the behavior of luggage in service.

II. Survey of Luggage in Actual Service

The first step in the investigation was to obtain information, both technical and general, concerning the materials used for, and methods of construction of luggage, as well as the treatment accorded it while in service.

Surveys were made in railroad stations at Salt

[1] Voluntary standards adopted by the trade. Commodity Standards Division, National Bureau of Standards, Washington 25, D. C.

Lake City, Utah; Chicago, Ill.; St. Louis, Mo.; Pittsburgh, Pa.; Bridgeport and Hartford, Conn.; Washington, D. C.; and Tampa and St. Petersburg, Fla. Baggage in intercity bus stations was surveyed in Pittsburgh, Pa.; Washington, D. C.; and Jacksonville and Tampa, Fla. Observations were made of baggage passing through the Washington National Airport and through La Guardia Field, N. Y., but no data were recorded. In selecting these cities, consideration was given to such variables as geographical location, size of city, and general characteristics of the traveling public and population (industrial, "white collar", or tourist) within the limitations of economy in the survey. The cities ranged in population from about 100,000 to over 3,000,000. The data obtained are regarded as sufficiently representative to serve as a guide in the development of performance tests designed to evaluate hand luggage.

1. Frequency of Types of Luggage

Surveys have been made of 5,804 pieces of luggage in the baggage rooms of railroads in the nine cities. The various styles of luggage in use in the geographic localities represented occur with the percentage frequencies shown in table 1.

TABLE 1. *Frequency distribution of types of luggage in railroad stations*

Type	Locality and number of surveys									
	Washington, D. C.,	Bridgeport, Conn.,	Hartford, Conn.,	Salt Lake City, Utah.,	Pittsburgh, Pa.,	Chicago, Ill.,	St. Louis, Mo.,	St. Petersburg, Fla.,	Tampa, Fla.,	All surveys,
	9	2	2	1	1	1	1	2	1	20
	FREQUENCY OF OCCURRENCE—PERCENTAGE OF TOTAL									
Field bag	3.0	1.3	2.5	3.2	1.2	0	0	0	0	2.5
Suitcase	32.1	26.7	29.8	16.1	38.8	50.4	23.8	32.1	50.0	32.2
Overnight case	4.2	2.7	7.4	3.2	1.2	2.4	1.8	18.9	3.3	4.4
Gladstone bag	6.9	2.7	9.3	0	11.2	8.1	3.7	5.7	3.3	6.9
Wardrobe case	15.2	22.7	13.0	12.9	18.8	6.5	5.5	24.5	20.0	14.4
Hat box	0.7	0	0	0	1.2	1.6	0	0	0	0.6
Sample case	2.1	4.0	1.9	3.2	1.2	6.5	29.4	0	0	4.1
Zipper bag	1.2	0	1.2	0	1.2	2.4	0	1.9	0	1.1
Boston bag	0.7	2.7	0.6	3.2	0	1.6	0	1.9	0	0.9
Valise	2.3	0	0	0	2.5	0	0	1.9	10.0	1.7
"Val-a-pak"	1.3	2.7	3.7	0	2.5	1.6	0	0	0	1.5
Hand trunk	3.4	4.0	1.9	12.9	0	0	0.9	0	0	2.6
Week-end case	13.6	22.7	19.9	19.4	11.2	3.3	5.5	0	0	12.9
Miscellaneous	13.3	8.0	8.7	25.8	8.8	15.5	29.4	13.2	13.3	14.3

The classifications used are those appearing on the form used by the Washington (D. C.) Terminal for reporting loss or damage claims. The miscellaneous classification includes such items as previously used paperboard boxes, golf bags, barracks bags, skis, etc.

These results show that three types, namely, week-end and overnight cases (considered as one type), suitcases, and wardrobe cases, are the most frequently used types in all the cities. They comprise 74.5 percent of all the units surveyed, exclusive of the miscellaneous classification.

The frequencies of occurrence of the types were also tabulated for bus stations in Pittsburgh, Washington, Tampa, and Jacksonville. The results, together with those obtained in the nine railroad stations, are shown in table 2.

The various types appear with approximately the same frequency in bus baggage rooms as in rail baggage rooms except for wardrobe, zipper bag, sample case, and miscellaneous classes. The miscellaneous group, for bus travel, contains a large number of sea and barracks bags, which count appreciably toward increasing the percentage frequency of occurrence over that found in railroad service. Zipper bags occur about four times as often in bus stations as in rail terminals. On the other hand, sample cases occur about four times more frequently in the rail terminals.

TABLE 2. *Frequency of occurrence of types of luggage in bus and railroad stations (percentage of total for each carrier)*

Carrier	Field bag	Suitcase	Overnight case	Gladstone bag	Wardrobe case	Hat box	Sample case
Bus	1.9	28.1	2.6	6.4	9.4	0.9	0.9
Railroad	2.5	32.2	4.4	6.9	14.4	.6	4.1

Carrier	Zipper bag	Boston bag	Valise	Val-a-pak	Hand trunk	Week-end case	Miscellaneous
Bus	4.9	0.9	1.1	0	3.4	16.5	23.1
Railroad	1.1	.9	1.7	1.5	2.6	12.9	14.3

Nine surveys were made in the Washington Terminal, some on different days of the week, and some at monthly intervals. No significant differences between these surveys were found.

Unlocked bags tend to be more easily damaged than locked ones, because of the possibility of locks and catches opening when severely jarred. It is, therefore, of interest that bus passengers apparently do not lock their luggage as often as rail passengers. The percentages of luggage found locked, half locked (one of the two locks unlocked) and unlocked, respectively, for bus travel were 37.5, 3.4, and 59.1, whereas for railroads these percentages, in the same order, were 49.5, 6.6, and 43.9.

Because of the relatively small volume of luggage carried by air lines, it appeared unlikely that any results of surveys would be sufficient to change the over-all conclusions as to the types of luggage to be studied, and complete surveys at air fields were not undertaken. It appeared probable from the observations made that the percentage of miscellaneous items and of Gladstone bags was less than that found on the railroads, and that the percentages of overnight, week end, and wardrobe cases were greater.

2. Frequency of Materials Used for Outer Coverings

The various kinds of covering materials observed and the percentage of each found in railroad and bus stations are given in table 3.

The material termed "fabric over chipboard* and/or veneer," popularly known as "airplane luggage," occurs more frequently than any other type of covering. This is true for both railroads and busses. In bus stations the next most frequently found material is "paper over chipboard and/or veneer," which amounts to about 22 percent of the bus luggage, excluding the miscellaneous classification. The percentages of all-leather cases, mostly Gladstone bags, are approximately the same for the two kinds of carriers, and rank second and third in occurrence, respectively, for rail and bus travel. Other kinds of materials are found in considerably smaller quantities in both kinds of stations. Metal cases are more popular with bus patrons than with railroad patrons. Fiberboard materials appear more frequently in the rail baggage rooms because of the higher proportion of sample cases carried on railroads.

The different types of materials, as found in various localities, are shown in table 4.

The distribution of materials does seem to be affected by locality. In Eastern and Midwestern cities people traveling by train use more fabric-

*Commonly known as cardboard.

TABLE 3. *Material distribution (percent)*

Carrier	Composition					
	Chipboard	Paper over chipboard and/or veneer	Imitation leather over chipboard and/or veneer	Fabric over chipboard and/or veneer	Split leather over chipboard and/or veneer	Fiberboard
Railroad	4.5	5.0	2.5	42.9	7.2	8.6
Bus	4.6	22.1	2.3	32.6	3.5	1.2

Carrier	Composition				
	Canvas	Metal	Leather	Plastic composition	Other materials
Railroad	6.3	4.3	16.5	1.1	1.1
Bus	7.0	7.0	14.0	2.3	3.5

TABLE 4. *Material distribution according to locality (percent)*

Locality	Material								
	Chipboard	Fiberboard	Paper or imitation leather over chipboard and/or veneer	Fabric over chipboard and/or veneer	Leather over chipboard and/or veneer	Canvas	Metal	Leather	Other
RAILROAD BAGGAGE ROOMS									
Washington, D. C	3.1	5.7	10.3	40.7	7.2	8.2	2.6	19.6	2.6
Bridgeport, Conn	6.1	10.2	4.0	51.1	2.0	8.2	4.1	14.3	—
Hartford, Conn	9.3	5.6	4.5	42.7	5.6	1.8	1.8	24.1	4.6
Salt Lake City, Utah	8.7	26.1	—	17.4	13.0	4.4	26.0	4.4	—
Pittsburgh, Pa	—	—	6.2	62.6	6.2	—	—	25.0	—
Chicago, Ill	—	9.5	—	23.9	19.0	14.2	9.5	23.9	—
St. Louis, Mo	—	35.7	7.1	43.0	7.1	—	7.1	—	—
St. Petersburg, Fla	6.5	—	8.7	60.8	10.9	4.4	—	6.5	2.2
Tampa, Fla	3.8	23.2	7.6	38.5	—	3.8	7.7	7.7	7.7
BUS BAGGAGE ROOMS									
Washington, D. C	—	—	21.1	36.7	—	15.8	10.5	15.8	—
Pittsburgh, Pa	15.4	7.7	30.7	15.4	—	—	7.7	23.1	—
Jacksonville, Fla	4.3	—	35.0	30.4	—	8.7	4.3	8.7	8.6
Tampa, Fla	3.2	—	16.1	38.7	9.7	3.2	6.5	12.9	9.7

covered cases than any other kind except in Chicago, where the proportions of fabric-covered cases and of leather cases are equal. In Salt Lake City fabric-covered bags are not the first choice but have been replaced by metal and fiberboard cases. In bus stations of the four cities surveyed, the fabric cases are the predominant type, Pittsburgh offering the exception, in which locality they are superseded in number by paper-covered bags and equaled by heavy chipboard cases.

Type of material and style are quite closely related in many instances. For example, Gladstone bags are almost always leather, and of nonrigid construction. Occasionally one finds them made of split leather over chipboard. Metal cases are generally of the suitcase size or hand-trunk style. Zipper bags usually appear with canvas covering, rarely in leather or oilcloth.

Table 5 shows, for the principal types of luggage, the percentage of cases of each covering material. Data for other types are available for persons interested in them.

Table 5. *Covering materials for principal types of luggage*

(Percentage of total for each type)

Type of baggage	Material							
	Chipboard	Paper or imitation leather over chipboard and/or veneer	Fabric over chipboard and/or veneer	Leather over chipboard and/or veneer	Fiberboard	Metal	Leather	Other
RAILROAD								
Suitcase	8.8	9.4	39.0	11.9	9.4	6.3	11.3	3.9
Overnight and weekend	4.8	11.4	60.6	10.8	4.8	1.7	5.0	.9
Wardrobe	1.2	6.0	83.3	2.4			3.6	3.5
BUS								
Suitcase	5.1	25.6	46.2	2.6		7.7	5.1	7.7
Overnight and weekend	5.0	48.3	33.3	1.3		5.0		7.1
Wardrobe	10.0	10.0	40.0	20.0		10.0		10.0

3. Weights of Luggage in Service

Overloading is often the cause of damage or failure of a case because of the handle giving way and adds greatly to the shock sustained by a falling case. Therefore, specimens examined during the surveys were weighed, and the over-all volumes of the bags were also measured. Table 6 lists the mean specific weights (pounds per cubic foot) of luggage for different volume ranges, as determined in 13 localities.

The values of the mean specific weights were used in calculating the loads to be used in specimens undergoing test in the laboratory.

The mean specific weights, for different volume ranges, are compared for rail and bus traffic in table 7.

Table 6. *Mean specific weight of luggage in different volume ranges*

Volume range	Locality—(Mean specific weight in lb/cu ft)									
	Washington, D. C.	Bridgeport, Conn.	Hartford, Conn.	Salt Lake City, Utah	Pittsburgh, Pa.	Chicago, Ill.	St. Louis, Mo.	St. Petersburg, Fla.	Tampa, Fla.	Jacksonville, Fla.
RAILROAD BAGGAGE ROOMS										
cu. ft.										
0.26 to 0.75	23.4	15.9	22.3	17.8	21.3	19.2	41.8	48.4	43.9	
0.76 to 1.25	17.9	16.0	15.9	18.4	14.8	22.1	20.1	24.1	21.5	
1.26 to 1.75	16.6	17.1	20.2	14.2	17.8	17.5	16.5	22.7	24.5	
1.76 to 2.25	15.4	13.8	15.1	15.4	19.4	13.5	18.9	20.9	18.1	
2.26 to 2.75	15.1	19.3	14.4	15.8	16.8	22.0	11.8	18.2	19.2	
2.76 to 3.25	13.4	14.7	15.2	14.2	16.2				15.4	
3.26 to 3.75	14.2	8.0		9.4						
3.76 to 4.25							23.5	15.0		
4.26 to 4.75										
4.76 to 5.25				2.7					16.9	
BUS BAGGAGE ROOMS										
0.01 to 0.25	16.7									
0.26 to 0.75	15.4				35.2				15.8	6.7
0.76 to 1.25	21.3				18.3				18.0	31.7
1.26 to 1.75	16.4				18.5				19.7	16.5
1.76 to 2.25	18.3				12.8				16.1	15.4
2.26 to 2.75	13.7				18.2				19.9	
2.76 to 3.25	12.9								24.6	
3.26 to 3.75	16.8				15.6					14.6

TABLE 7. *Comparison of mean specific weight for different volume ranges*

Volume ranges, cu ft	Rail	Bus
	lb/cu ft	*lb/cu ft*
0.01 to 0.25	----------	16.7
0.26 to 0.75	29.7	17.3
0.76 to 1.25	18.7	22.2
1.26 to 1.75	18.4	17.8
1.76 to 2.25	16.1	15.8
2.26 to 2.75	16.2	16.5
2.76 to 3.25	14.2	16.8
3.26 to 3.75	13.2	15.9
3.76 to 4.25	19.3	----------
4.26 to 4.75	----------	----------
4.76 to 5.25	9.8	----------

4. Condition of Luggage in Service

At the time that the cases were being examined for type, in both rail and bus terminals, appraisals of the items were made regarding their condition and appearance. Four grades of condition were used, approximately as follows:

Excellent: No damage other than soiling or abrasion which has not broken the surface

Good: Scuffs, scratches, dents or similar defects

Fair: Tears or breaks in outer covering, red rot in leather, but no puncture completely through walls; hardware damaged but still operable

Poor: Failure of hardware, handle, frame, wall; or exposure of contents

Variations in the over-all condition of luggage as found in stations in different localities are shown in table 8.

TABLE 8. *Condition of luggage in rail and bus stations*

Locality	Excellent and good	Fair and poor
RAILROAD STATIONS		
	Percent	*Percent*
Washington, D. C	57	43
Bridgeport, Conn	56	44
Hartford, Conn	58	42
Salt Lake City, Utah	61	39
Pittsburgh, Pa	60	40
Chicago, Ill	49	51
St. Louis, Mo	42	58
St. Petersburg, Fla	51	49
Tampa, Fla	60	40
Average	55	45
BUS STATIONS		
Washington, D. C	49	51
Pittsburgh, Pa	41	59
Jacksonville, Fla	38	62
Tampa, Fla	59	41
Average	47	53

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In all but two railroad stations, the number of bags in excellent and good condition exceeds those in fair and poor condition. The opposite seems to be true for bus travel in three of four cities.

The comparison between railroad and bus baggage indicates that somewhat more cases of better quality are encountered in railroad baggage rooms than in bus baggage rooms.

5. Types of Damage in Service

A study of the types of damage occurring in service and the experience of baggage agents show that the majority of damages falls into these classes:

1. Broken or bent hardware (catches, locks, hinges).
2. Broken handles.
3. Separation of frames, or of covering from frame.
4. Punctures of surfaces (sides, ends, bottom, top).
5. Scuffing and tearing of covering or binding.
6. Damage by water, grease, oil, etc.

The last item rarely leads to damage of the contents, or to permanent impairment of the functional operation of the bag, although objectionable discoloration may result. Scuffing or tearing of the covering, although disfiguring, does not usually expose the contents of the bag or damage it to such an extent as to render it useless. The first four items are considered to be the most serious causes for damage and loss of luggage and contents, and attention was concentrated on them in laboratory studies.

Typical examples of damage occurring in actual service are illustrated in figures 1, 2, and 3.

Types of damage to hardware are pictured in figure 2.

Four of the ways in which a handle may fail are shown in figure 3.

The loss of a handle in service is serious not only from the standpoint of inconvenience to all who must carry the bag, but also because its detachment may cause the whole case to be lost, as identification tags or checks are usually attached to the handle. Loss of the handle or failure of a component part sometimes results in serious damage to the case itself by causing a fall from a considerable height onto a hard surface, as when the failure occurs because the handle is being used to pull the bag from a rack.

Some serious failures are caused by external loads, from other luggage stacked on a bag, or similar conditions. Luggage may be stacked to a height of several feet as a space-conserving measure. There is sometimes a tendency to force a small bag into insufficient residual space in a packed compartment, with the result that a compressive force is exerted on all bags in the compartment. A much more prevalent practice is that travelers often use luggage for other than its intended purposes, such as a seat or a stepladder to gain access to overhead baggage racks. It is estimated that static external loads of 100 to 200 pounds are quite frequent, and that loads up to 400 pounds may occasionally be found.

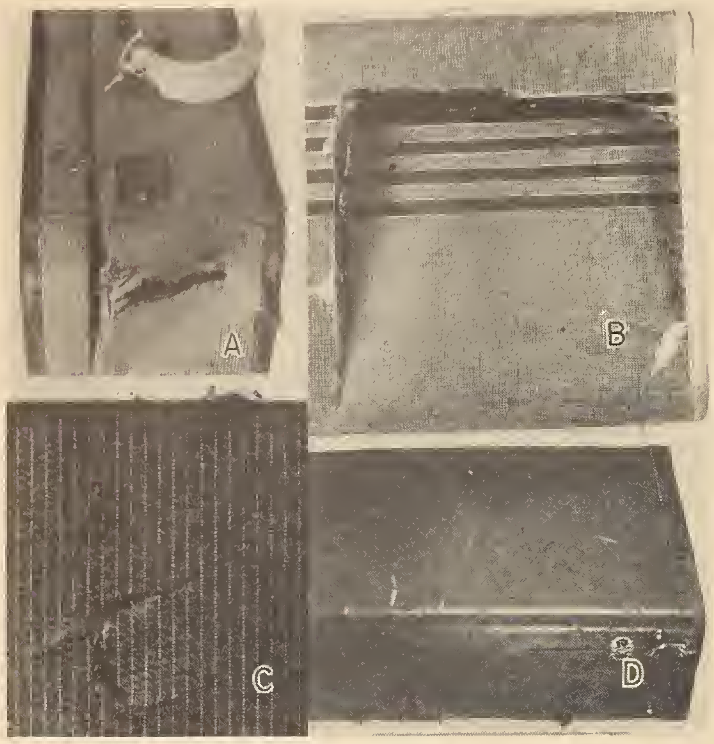

FIGURE 1. *Types of damage to luggage in actual service.*
A, Broken frame; *B*, rectangular fracture of plywood; *C*, puncture of surface; *D*, scuffing of leather.

FIGURE 3. *Types of damage to luggage handles in service.*

Top, handle broken away from D-ring, and metal reinforcement in handle pulled out; second, handle disappeared in service; third, rivets fastening handle plate to bag pulled through top of bag; bottom, leather handle broke across slot through which passed metal pin fastening it to bag.

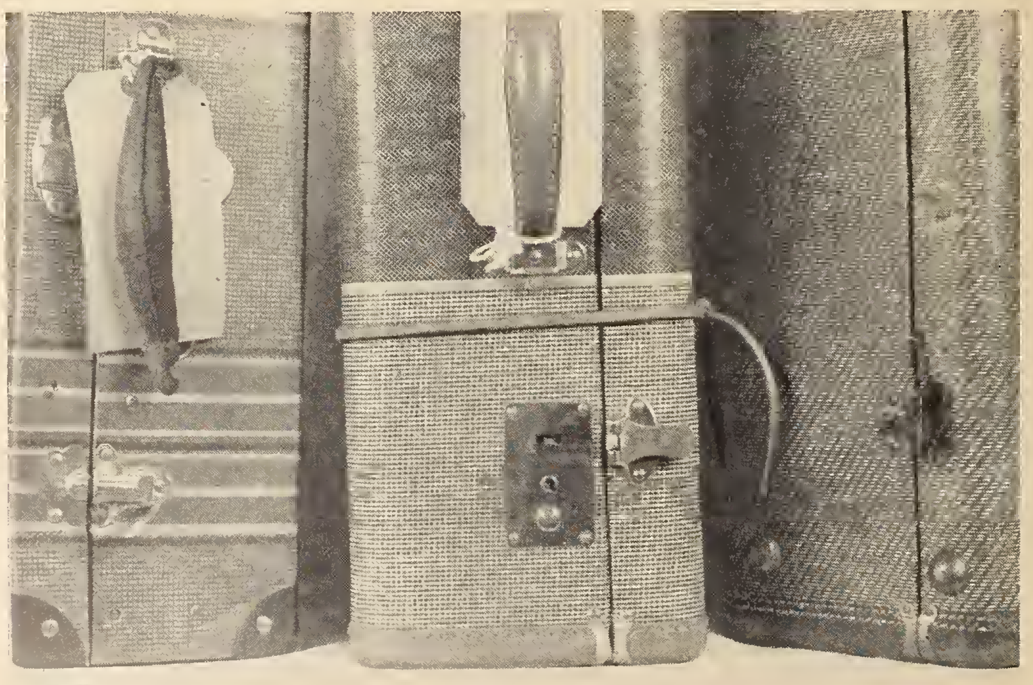

FIGURE 2. *Types of damage to luggage hardware in service.*

Right, hinge failure caused by rivets pulling out; center, hasp of internal-type catch broken at spot-welds; left, movable piece of external-type catch bent and pulled out at one side.

Bags may drop from various heights in service because of handle breaks, methods of handling and stacking, and other reasons. Luggage has been seen to fall from a height of 6 feet after being carelessly stacked on older style trucks. Occasionally the failure of a handle may lead to dropping a bag on a station floor; sometimes the bag then opens and scatters the contents. One type of impact peculiar to air lines is that caused by the sudden rise or fall of the plane in turbulent air. In extreme conditions a force of two to three times gravity may be imposed.

The surfaces of bags are sometimes fractured in service, either by falling on sharp objects, or by sustaining a blow from a falling object, such as the corner of another bag. Damage is apt to be more severe for a rigid type of container, such as fiberboard or veneer construction, particularly when the surface is not supported by full packing within the bag.

III. Description of Luggage Used in Experiments

1. Types and Sizes

In order to obtain information on the effect of types of materials, sizes, etc., to the maximum extent consistent with practical limitations on the number of bags to be studied, luggage for test was purchased according to the following scheme. (The figures in parentheses give the approximate retail price, with tax, in June 1947.)

Bags about 21 inches long:
1. Chipboard ($2.50).
2. Vulcanized fiberboard ($6).
3. Fabric cover:
   a. Lower-priced ($12).
   b. Higher-priced ($18).
4. Plastic cover ($20).
5. Leather cover ($36).

Bags about 26 inches long:
1. Chipboard ($3.50).
2. Vulcanized fiberboard ($12).
3. Fabric cover:
   a. Lower-priced ($17).
   b. Higher-priced ($27).
4. Plastic cover ($33).
5. Leather cover ($51).

The two sizes, 21 inches and 26 inches, were selected because these represent the most popular sizes used, according to surveys. The smaller size represents approximately week-end, overnight, and other small cases; the larger size is similar to wardrobe, pullman, fortnighter cases, and the like. Three identical specimens of each group were purchased in the open market; two were tested in the laboratory; and the third was subjected to an actual service test.

2. Chipboard Cases

The unused chipboard cases are shown in figures 4, A, and 5, A. The smaller bag was 23 inches

FIGURE 4. *Small chipboard case.*
A, Unused; *B,* after laboratory tests; *C,* after service test.

FIGURE 5. *Large chipboard case.*
A, Unused; *B*, after laboratory tests; *C*, after service test.

long, somewhat longer than the usual week-end case,[2] but was sold as a week-end case in a matched set with the larger bag. These bags, retailing for about $2.50 and $3.50, respectively, are designed and striped so as to resemble the fabric-covered "airplane" luggage. They have a partial frame of wood, about 3/8 inch thick, which extends under and supports only about half the top, bottom, and ends of the main body of the case, and appears to have as its principal function the provision of an anchorage for the hardware. The hardware was of very light weight.

The handles of this type of bag were made of a split leather covering over paper composition, containing a strip of reinforcing metal that was doubled over a D-ring at each end. The D-rings passed under metal plates, which were attached to the body of the bag by split rivets.

[2] Simplified Practice Recommendation R215–46 (Jan. 1, 1946).

3. Vulcanized Fiberboard Cases

Photographs of the unused vulcanized fiberboard cases are shown in figures 6, A, and 7, A. The retail prices of these cases were approximately $6.00 and $12.00 for the smaller and larger sizes, respectively. These cases were made almost entirely of thick vulcanized fiberboard, treated with a coating that seemed to be an alkyd resin. They had black metal bindings, and the surfaces were fastened at the edges with a large number of black metal rivets. There was no reinforcing frame. The hardware was moderately heavy.

The handles were formed of leather over paper composition, reinforced by a metal wire or rod about 1/8 inch in diameter, which passed through steel buttons at each bend, and was flattened at the end to prevent the buttons from becoming detached. The ends of the handle passed under sheet metal strips, about 1/2 inch wide, which were riveted to the body of the case, the rivets passing through a sheet of reinforcing material of the same composition as the body of the case.

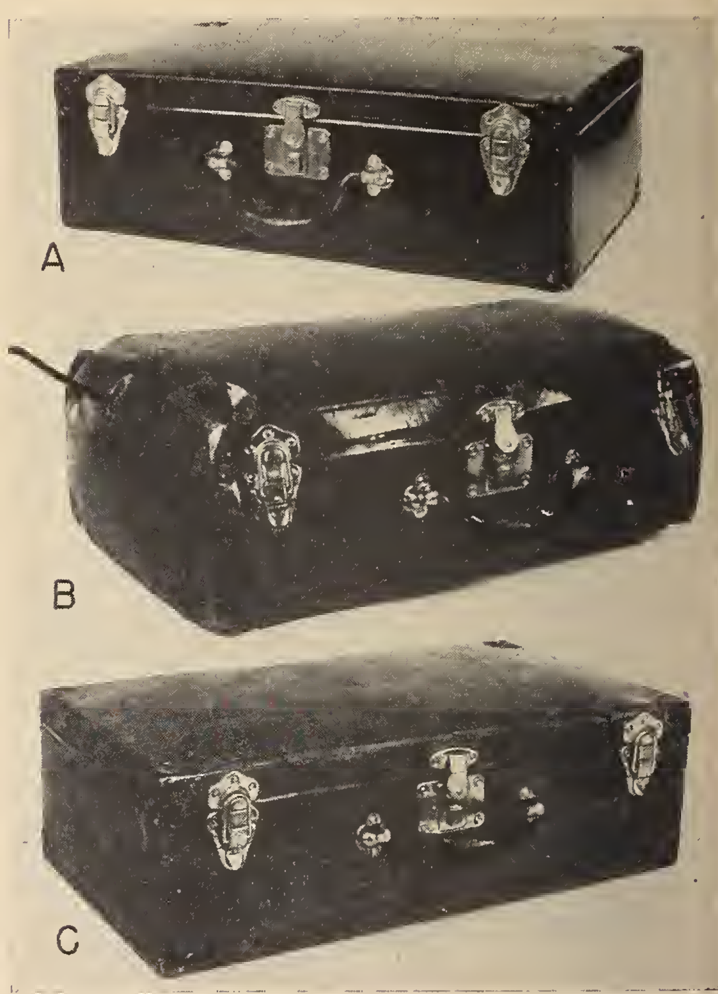

FIGURE 6. *Small vulcanized fiberboard case.*
A, Unused; *B*, after laboratory tests; *C*, after service test.

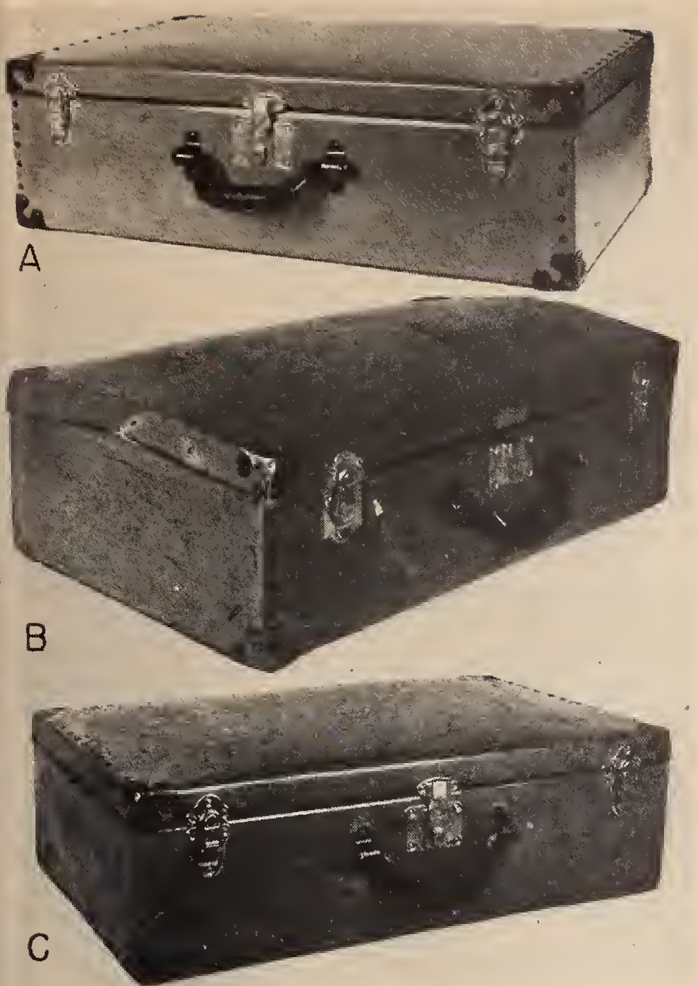

Figure 7. *Large vulcanized fiberboard case.*
A, Unused; *B,* after laboratory tests; *C,* after service test.

4. Lower-Priced Fabric-Covered Cases

The unused lower-priced fabric-covered cases are shown in figures 8, A, and 9, A. The retail prices were about $12.00 for the 21-inch and $17.00 for the 26-inch size. They had certain components reputed to cause trouble in service, namely, chipboard sides under the fabric, spot-welded hasps on the internal-type catches, and hardware generally of light weight.

The handles were composed of a double thickness of heavy impregnated fabric, sewn together at the edges, and looped at the ends over two 1-inch D-rings. The D-rings passed under metal handle plates, which were fastened to the body of the bag by bent extensions of the plates themselves.

5. Higher-Priced Fabric-Covered Cases

The unused higher-priced fabric-covered cases, retailing at about $18.00 and $27.00 for the smaller and larger sizes, respectively, are shown in figures 10, A, and 11, A. The most obvious differences from the less expensive fabric-covered cases were that the fabric was more closely woven, that the bodies of the cases were wood veneer instead of chipboard, and that the hardware was all brass and of heavier weight. The hasps on the catches were not simply spot-welded, but extended through two small holes in the hinged metal part of the catch.

The handles were of the post type, and were made of leather over paper composition. Through

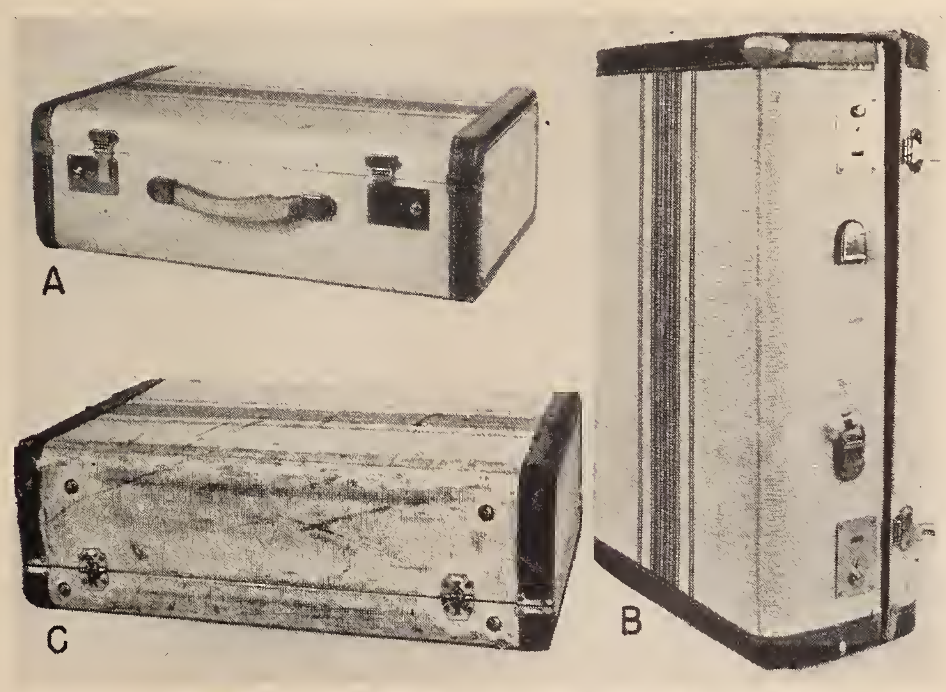

Figure 8. *Lower-priced small fabric-covered case.*
A, Unused; *B,* after laboratory tests; *C,* after service test.

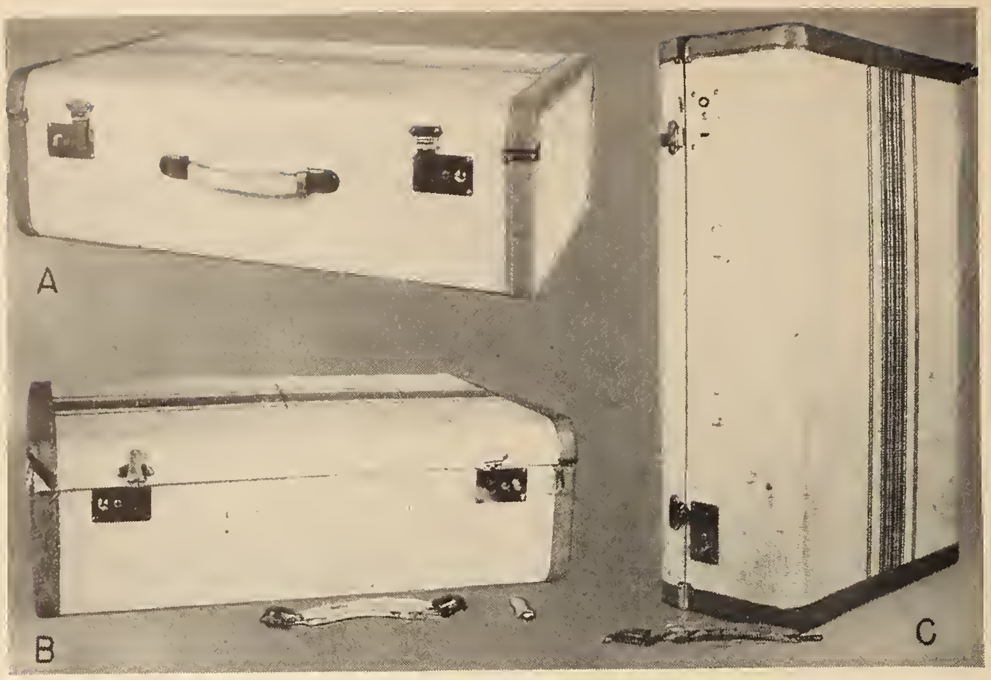

FIGURE 9. *Lower-priced large fabric-covered case.*
A, Unused; *B,* after laboratory tests; *C,* after service test.

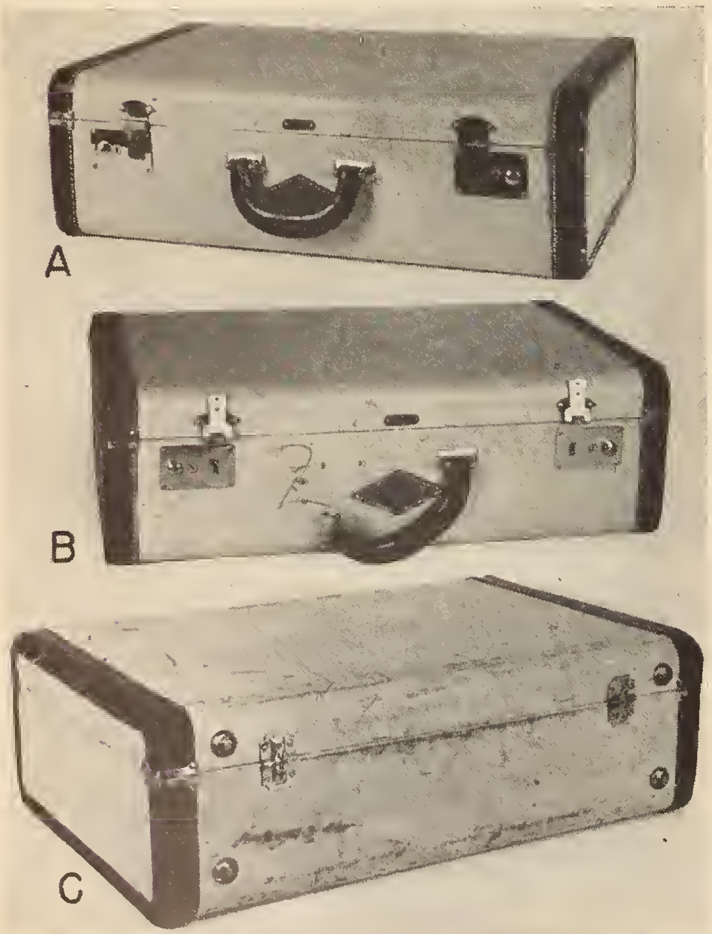

FIGURE 10. *Higher-priced small fabric-covered case.*
A, Unused; *B,* after laboratory tests; *C,* after service test.

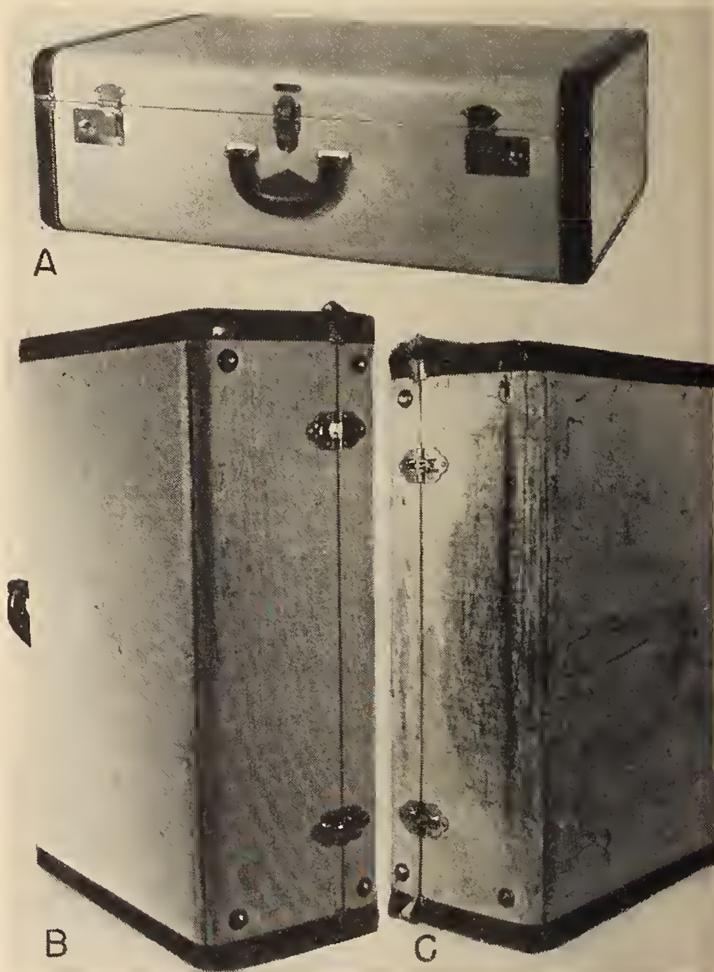

FIGURE 11. *Higher-priced large fabric-covered case.*
A, Unused; *B,* after laboratory tests; *C,* after service test.

the ends of the handles passed a brass pin, the ends of which were held by hollow metal posts, projecting from a brass plate fixed to the bag by bent metal strips that passed through the body of the bag and then bent at right angles.

6. Plastic-Covered Cases

The plastic-covered cases were made of wood veneer to which was bonded a surface coating of a cellulosic plastic, probably cellulose nitrate. The unused bags are shown in figures 12, A, and 13, A. This material has become increasingly popular in recent years, and among baggagemen it has a good reputation for durability. It has a glossy brown finish, with an embossed pattern somewhat resembling alligator leather. The larger case was bound with metal, liberally riveted, and the smaller with leather. The hardware on both bags was quite heavy, the catches being of a modified external tension type. Retail prices, about $20.00 for the smaller and $33.00 for the larger bag, seemed to be quite uniform at different dealers. The handle was made of rubber, molded over a metal strip which passed around a pin fastened to a brass plate, in turn fastened to the case with bifurcated rivets. This fastening assembly was covered with a brass housing, presumably to protect it from impacts.

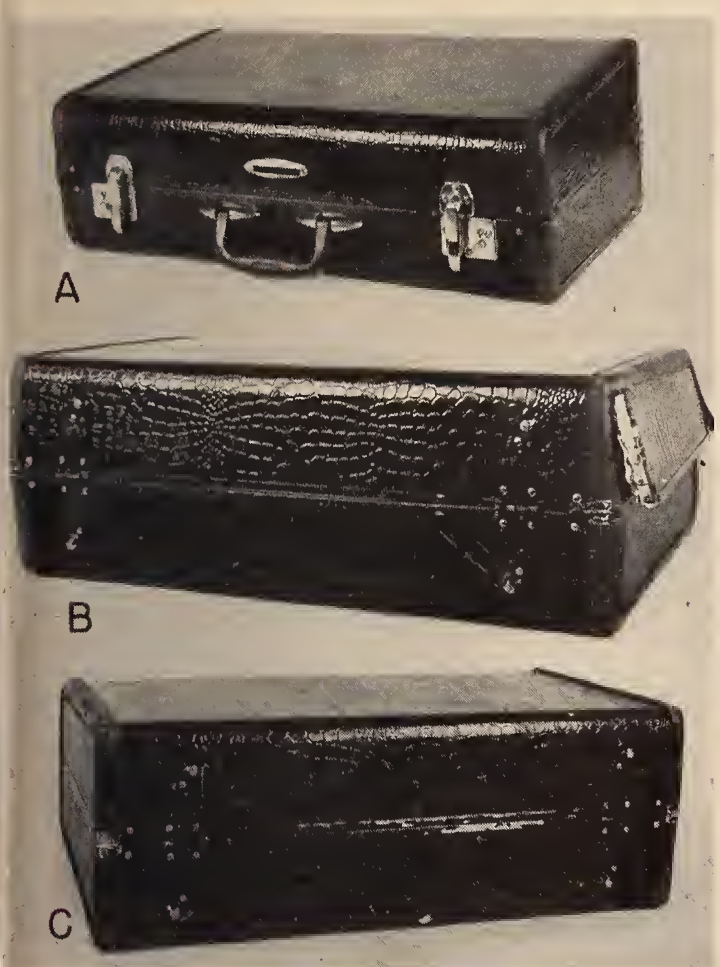

FIGURE 12. *Small plastic-covered case.*
A, Unused; *B*, after laboratory tests; *C*, after service tests.

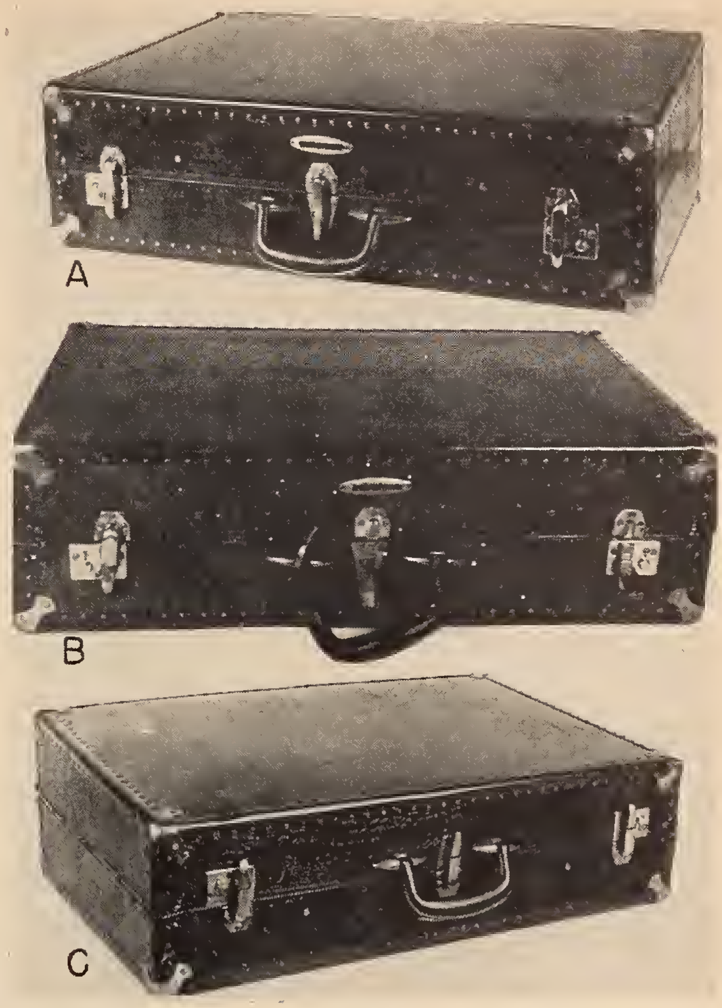

FIGURE 13. *Large plastic-covered case.*
A, Unused; *B*, after laboratory tests; *C*, after service tests.

7. Leather-Covered Cases

The unused leather-covered cases are shown in figures 14, A, and 15, A. They cost about $36.00 and $51.00 for the 21-inch and 26-inch bags, respectively. They had wood veneer bodies, covered and bound with grain leather splits. Their hardware was all brass, of a moderately heavy grade; the hardware and handles were similar to those of the higher-priced fabric-covered cases.

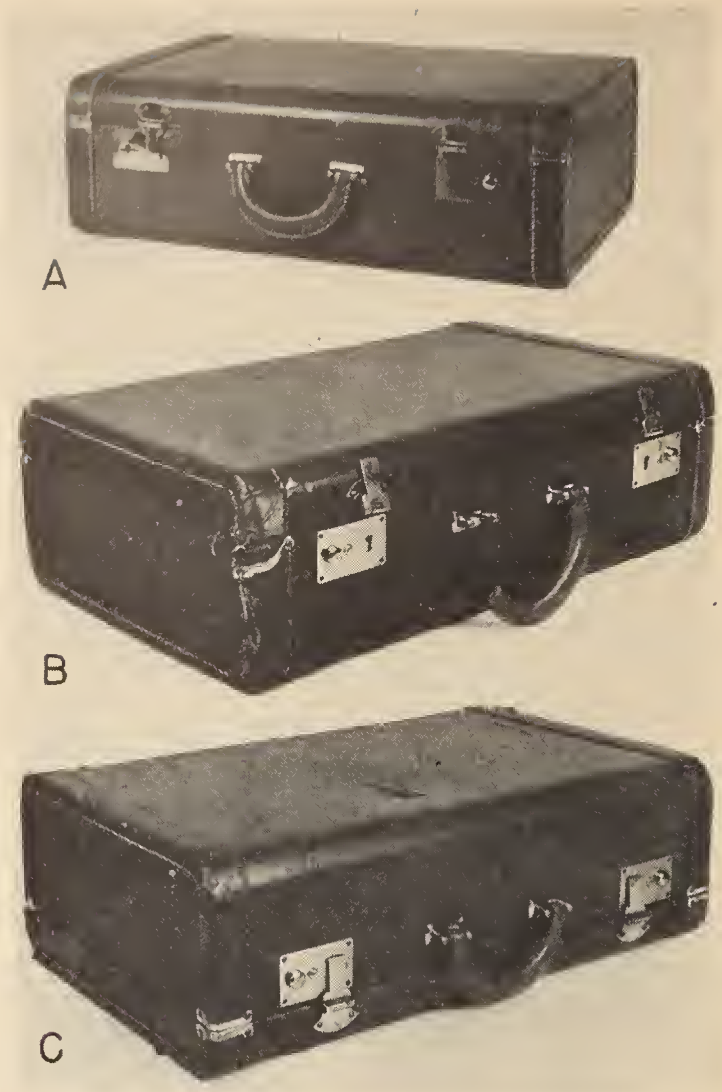

FIGURE 14. *Small leather-covered case.*
A, Unused; *B*, after laboratory tests; *C*, after service tests.

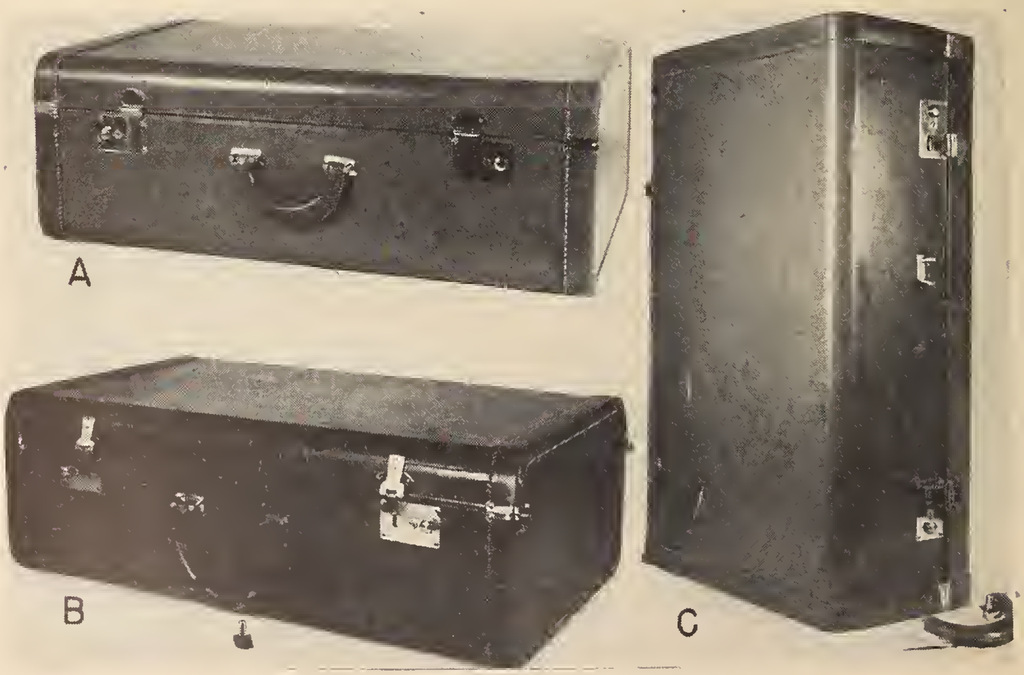

FIGURE 15. *Large leather-covered case.*
A, Unused; *B*, after laboratory tests; *C*, after service tests.

IV. Laboratory Tests

1. Description of Test Methods

Five physical tests were used for the qualitative and quantitative reproduction, in the laboratory, of the damage occurring in service. These are designated the handle fatigue test, the static load test, the divided-table drop test, the puncture test, and the revolving drum test. The static load test is made with the bag empty, since in this condition it does not offer the added resistance afforded by tight packing. The puncture test is made on segments cut from the walls of the bag. The other three tests are made on loaded bags, since this condition reproduces the more severe conditions to be expected in service. The loads used (including the weights of the bags themselves) were calculated from the results of the surveys. For each volume range, the mean specific weight plus three times its standard deviation was taken and the result multiplied by the midpoint of the range. This figure, called the "maximum expected load," represents a weight that would not be expected to be exceeded more than three times in a thousand in actual service. The maximum expected loads are shown in table 9.

Table 9.—*Maximum expected loads (suggested for laboratory tests of loaded luggage)*

Volume of piece, cu ft	Total load
	lb
Under 0.75	22
0.76 to 1.00	29
1.01 to 1.25	36
1.26 to 1.50	43
1.51 to 1.75	50
1.76 to 2.00	57
2.01 to 2.25	64
2.26 to 2.50	71
2.51 to 2.75	78
2.76 to 3.00	82
3.01 to 3.25	86

The bags were loaded as much as possible with clean, household rags, with from three to six common bricks, depending on the size of the bags. The bricks were covered with cloth and located centrally in the bags so that they could not shift in position when the bags were tested.

In describing damage and other characteristics of the bags in the laboratory, it is convenient to identify the faces, edges, and corners of a bag by a numerical system. The ASTM method for shipping containers was used. In applying this method, the bag is laid on its side, the handle toward the observer and the lid at the top, in the position customarily used for opening or packing. The lid is designated as face number 1; the handle face, number 2; the face opposite the lid, number 3; and the bottom or hinge face, number 4. The end at the observer's left is number 5 and the one at his right, number 6. The edges are identified by the numbers of the two faces that intersect to form that edge; for example, 1–2 identifies the edge where the lid and handle side meet. The corners are identified by the numbers of the three faces that meet to form that corner. For example, 1–2–5 identifies the corner where the lid, the handle side, and the left end meet. This system was used throughout the tests to record the location of damage. It is applicable, in modified form, to pieces of luggage that are not essentially rectangular parallelepipeds, such as Boston bags and hat boxes.

(a) Handle Fatigue Tests

The apparatus designed for the handle fatigue test is shown in figure 16. It picks bags up and sets them down repeatedly in a manner simulating the action of a person picking up a bag by hand and setting it down. The device operates at the rate of 37.5 pickups per minute, and exerts a peak force of approximately 1.8 times gravity, as measured against a 50-pound weight. It is

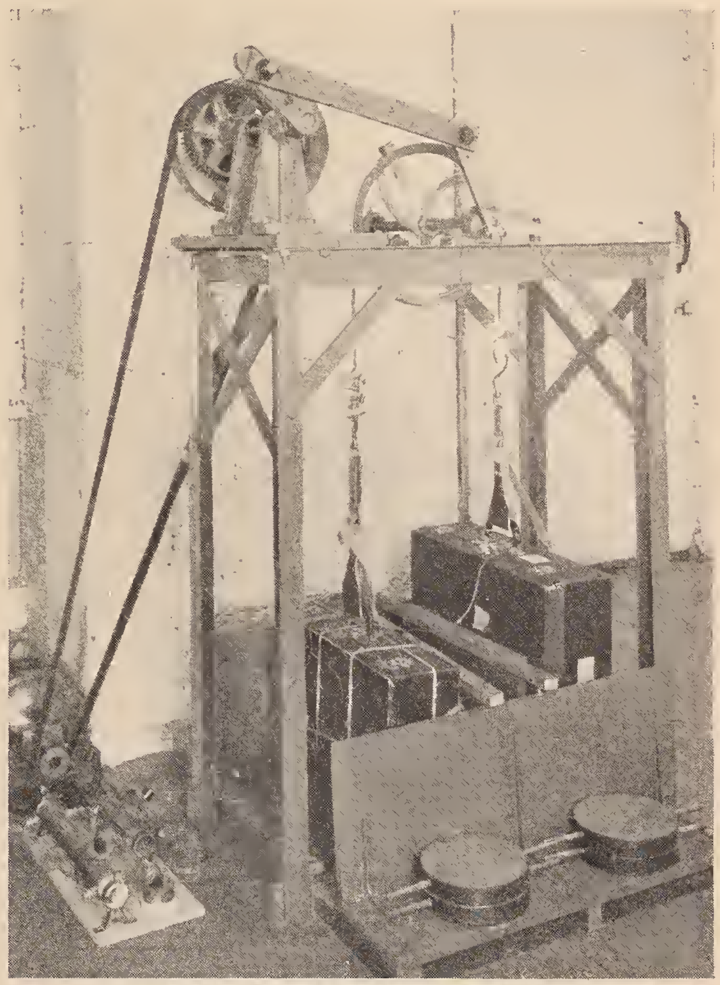

Figure 16. *Handle fatigue test apparatus.*

equipped with an electrical relay system that stops the operation as soon as a handle fails, and an automatic counter that records the number of pickups. Intended primarily to evaluate the durability of handles, the machine also stresses the hardware and the frames. The results of this test appear to approximate closely the behavior of handles in actual service, even though in service they may be exposed to other types of forces.

(b) Static Load Tests

For the static load test, a weight of 150 pounds, occupying an area 5 by 8 inches, was placed successively on the center of a side, end, and top of an empty, closed bag, and allowed to remain in each position for 5 minutes. Permanent deformation, breakage, or tearing indicated failure of the specimen. Permanent creasing of the covering material, although disfiguring, was not considered a failure.

(c) Divided-Table Drop Test

This test is made by means of a device that permits the loaded bag to be dropped on any edge, surface, or corner. The apparatus is illustrated in figure 17 and meets the requirements of the ASTM Designation D775–45T.[3]

The procedure consisted in dropping the loaded bag successively on each of the surfaces, edges, and corners from heights of 1½, 2, 2½, 3, 3½, 4, 4½, and 5 feet. Thus 26 falls were made at each of the indicated heights, or until failure occurred. After each fall, the specimens were examined and damages were described and recorded.

In order to provide a quantitative measure of the performance of the bags, an arbitrary system for assigning scores for each fall was developed. Each bag, before starting the test, was given a rating of 1.11. As long as no damage was sustained, the bag was given a score of 1.11 for each fall. When the bag received some injury, a value commensurate with the severity of the damage was subtracted from the starting score. The bag was then assigned this new score for each subsequent drop until further damage occurred, when an additional deduction, again proportional to the severity of the damage, was made. This procedure was continued to the end of the test. The total score for any bag was the summation of its scores for the individual falls. Failure of the bag, or the reduction of the score to zero, at any drop, resulted in the summation of the scores up to that point. Thus, a bag failing at a low elevation (early in the test) would have a low total score. A bag withstanding drops from all eight heights, but suffering considerable damage at the lower heights, would have a lower score than one that also dropped from the eight positions but was

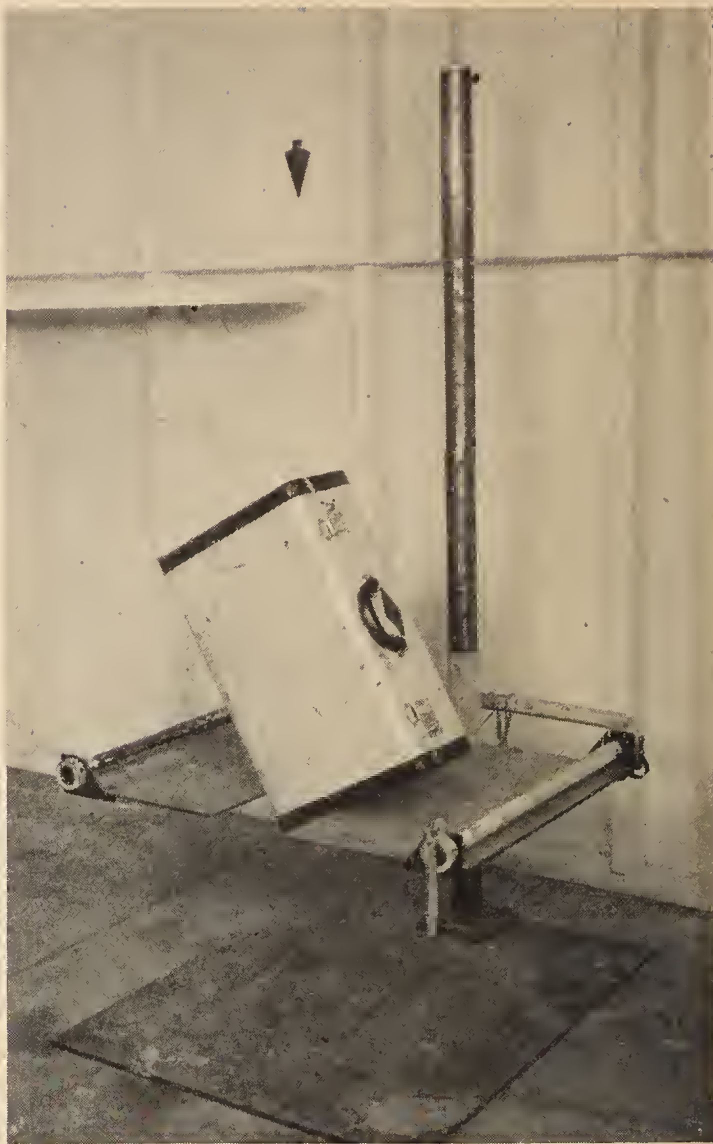

Figure 17. *Divided-table drop test apparatus.*

damaged at the higher levels. Hence, the system gives due credit to a bag for its ability to withstand punishment as the test progresses. A bag showing no damage at all would have been dropped 208 times, and have a total score of 230.81.

The reductions in score were made in accordance with an arbitrary schedule. The penalties ranged from 0.01 to 0.50, depending upon the seriousness of the damage and the probable effect on the future performance of the bag. The complete system for score reductions is shown in table 10.

Where a range is shown, the value selected depends on the severity of the damage. Three observers independently assigned and calculated scores for all the test specimens and obtained good agreement for the total numerical scores of each bag, the root-mean-square variation averaging less than 4 percent.

Bags were classified as failures because of handles completely pulled or broken loose, broken frames, all latches broken or inoperative, or large tears in the surface. With the exception of dam-

[3] ASTM Methods of Standards part III, B, p. 1266 (1946).

TABLE 10. *Score reductions for drop test*

Location	Type of damage	Score reduction
Bindings (leather)	Loose	0.05 to 0.1.
Do	Scuffs	0.01 to 0.1.
Do	Tears (1 in.)	0.02.
Do	Tears (½in.)	0.01.
Bindings (metal)	Bent	0.01.
Do	Broken	0.03 to 0.05.
Do	Loose	0.02.
Do	Off	0.03 to 0.05.
Corners	Dented (restorable)	0.01 (for each time). 0.05 maximum.
Do	Dented (permanent)	0.05.
Do	Metal supports loose	0.05.
Covering material	Abrasion	0.01
Do	Gouges	0.01 to 0.1.
Do	Loose from frame	0.05.
Do	Scuffs (body)	0.01 to 0.03.
Do	Scuffs (on edge)	0.01 to 0.1.
Do	Tears (small)	0.01.
Do	Tears (large)	0.05.
Edges	Separation beneath covering material.	0.02.
Do	Softened	0.01.
Frames (main body material).	Breaks (small)	0.05 to 0.2.
Do	Breaks (severe)	Failure.
Frames (main body material).	Creases (disfiguring)	0.01.
Do	Dents (small)	0.01.
Do	Dents (large)	0.05.
Do	Distorted	0.05 to 0.1.
Do	Misalined	0.02 to 0.1.
Do	Punctures (1 in.)	0.1.
Do	Punctures (2 in.)	0.5.
Do	Punctures (greater than 2 in.)	Failure.
Do	"Racking"	0.02 to 0.1.
Handles	Bent (nonrestorable)	0.01 to 0.1.
Do	Bent (restorable)	0.01.
Do	Loose	0.05.
Do	Off (one side)	0.5.
Do	Off (both sides)	Failure.
Handle plates	Posts bent	0.1.
Hasps	Beginning to pull loose	One fifth of total damage.
Do	Broken off	$1/n$ [a].
Hinges	Bent	0.02.
Do	Other damage	0.01 to 0.1.
Do	Torn off	$1/n$ [a].
Hinge lugs	Breaking through frame	0.1.
Latches and locks	Bent	0.1.
Do	Dented	0.01 to 0.05.
Do	Inoperable	$1/n$ [a].
Do	Loop type, loose (restorable).	0.01 for each time. 0.1 maximum.
Do	Opens continuously (restorable).	0.01 for each time. 0.1 maximum.
Lids or sides	Bulges open slightly	0.01 for each time. 0.05 maximum.
Do	Bulges open about 1 in	0.05 for each time. 0.1 maximum.
Do	Bulges open more than 1 in.	0.1 for each time. 0.2 maximum.
Lugs, standing	Off	0.02.
Rivets	Loose or out (corner plates).	0.02.
Do	Loose or out (edge binding).	0.01.
Do	Loose or out (handle plates, latches, hinges, locks).	0.03.

[a] $1/n$ (n=total number hasps, hinges, locks, or latches present on bag.) For example, if a bag has two hasps and one lock, the score reduction for breakage of one hasp or one lock is ⅓. If it has two hinges, the reduction for breakage of one hinge is ½.

age to the handle, all these resulted in exposure of the contents, a condition that seems sufficient reason for listing the bag as a failure.

(d) Puncture Test

For this test the General Electric puncture tester was used. This device, shown in figure 18, has been in use for some time in testing paperboard shipping containers.[4]

[4] Tentative Method of Test for Puncture and Stiffness of Paperboard, Corrugated and Solid Fiberboard, ASTM Designation D781-44T ASTM Methods of Standards, part III, B, p. 1238 (1946).

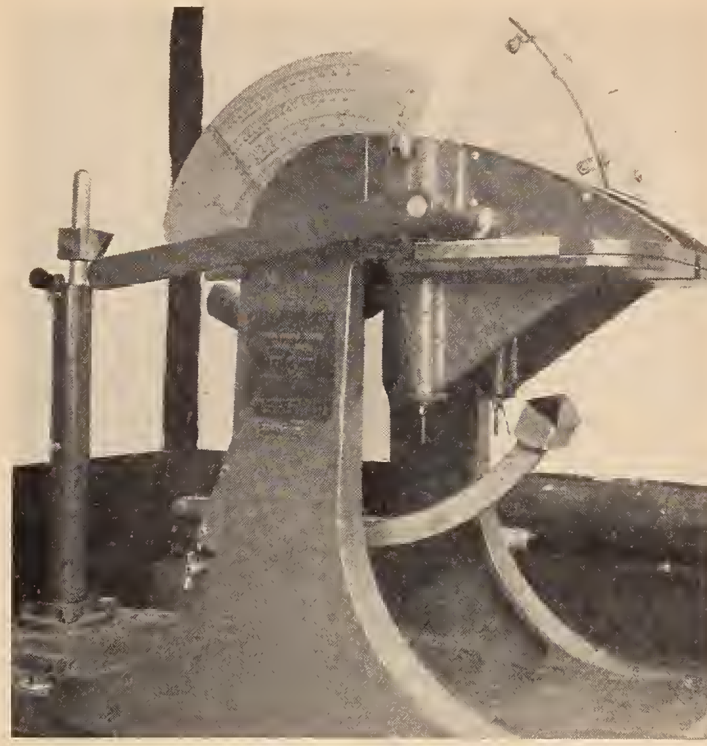

FIGURE 18. *Puncture test apparatus.*

In making this test, the bag is dismantled, and the surfaces only, not the loaded bag, are used. Sides were punctured six times, ends once, and tops and bottoms twice. The results, in inch-ounces, were read from the scale. They were compared without correction for thickness.

(e) Revolving Drum Test

Preliminary tests of several specimens were made similarly to the "Tentative method of drum test for containers in small revolving hexagonal drum box-testing machine."[5] The loaded bag was placed in the drum, which contained a series of baffles and hazards, so arranged that when the drum revolves about its horizontal axis, the bag is subjected to successive falls in different positions.

The results of this test appeared to represent well the behavior that was to be expected or had been experienced for bags in actual service. However, since the cost of such a drum is rather large and it requires much laboratory space, and since substantially the same results are given by the divided-table drop tester, it was thought unnecessary to continue the study of the revolving drum at this time.

2. Results and Discussion

(a) Handle Fatigue Test

The results of handle fatigue tests are given in table 11. The tests were discontinued at 50,000 pickups if no failure appeared.

[5] ASTM Designation D 782-44T, ASTM Methods of Standards, part III, p. 1315 (1944).

Table 11. *Results of handle fatigue tests*

Bag No.	Identification	Number of pickups: Bag not subjected to previous test	Number of pickups: Bag previously subjected to drop test	Type of failure
1	Chipboard, small	37,470	17,920	Reinforcing strip broke; D-ring spread.
2	Chipboard, large	16,180	35,120	Reinforcing strips broke.
3	Vulcanized fiberboard, small	50,000	50,000	
4	Vulcanized fiberboard, large	50,000	50,000	
5	Fabric-covered, lower-priced, small	50,000	50,000	
6	Fabric-covered, lower-priced, large	11,230	[1]	Metal strip holding handle plate to case pulled out.
7	Fabric-covered, higher-priced, small	13,260	11,630	Do.
8	Fabric-covered, higher-priced, large	4,140	5,830	Do.
9	Plastic composition, small	50,000	29,150	Reinforcing strip broke.
10	Plastic composition, large	11,490	26,780	Do.
11	Leather, small	50,000	9,090	Posts spread, releasing pin. Reinforcing strip broke.
12	Leather, large	17,500	[1]	Do.

[1] Handle broken in previous test.

It is notable that seven of the fourteen observed failures were caused by fracture of the metal reinforcing strip passing through the handle. Five were caused by bent metal strips fastening the handle plate to the body of the bag becoming straightened out under continued stress, and pulling out of the bag.

The results strongly indicate that a satisfactory handle will withstand at least 25,000 pickups. Twelve of the 22 handles reported here were capable of this performance, and the majority of these were found on inexpensive bags. Most of the failures were due to causes that would not be difficult to remedy. It may seem that 25,000 pickups far exceed the number of times that a bag will be picked up during its lifetime, but if one considers the vertical component of the fluctuating stresses received while the bag is carried by a pedestrian, the total number of up-and-down stresses may well be of the order of magnitude of 25,000. Certainly the number of handle failures occurring in actual service indicates that improvement in some bags is desirable, and this test points out improvements that could easily be effectuated.

(b) Static Load Test

Static load tests were made on only one set of the duplicates, as it was preferred not to strain all the bags prior to the drop tests.

Nine of the 12 bags tested were entirely satisfactory under these conditions of external loading. Even the flimsier cases were not complete failures. Application of the load to three bags, the small fiberboard and the small and large models of the chipboard resulted in some buckling and caving in of the structure. In this respect, these three bags must necessarily be rated somewhere lower than the others but not severely as the damage inflicted was not very serious. The loading caused no tears or structural breaks but did result in marring the appearance of the cases, through creasing and slight distortion, which, of course, would not seriously affect the usefulness of a bag in service. Any bag failing to withstand this moderate degree of external loading would certainly not offer satisfactory performance in actual use where heavier loading and greater force of application of the load are likely to be encountered.

(c) Divided-Table Drop Test

In table 12 are listed the averages of scores of each set of duplicates for the various styles, resulting from the divided-table drop test. It is to be noted that in all instances except one, the average score of the larger sizes is less than for the corresponding smaller sizes. In the case of the exception, the score is practically the same for both sizes. The results indicate that large-sized cases are much more prone to suffer damage on dropping than are small cases.

The chipboard cases received the lowest average drop rating. The poor construction and inherently weak materials of which they were composed were the responsible factors. The fabric-covered bags were somewhat stronger and resisted damage throughout the dropping slightly better than the chipboard.

Table 12. *Results of drop tests—score values*

Bag No.	Identification of bag	Score
1	Chipboard, small	30.2
2	Chipboard, large	25.2
3	Vulcanized fiberboard, small	139.4
4	Vulcanized fiberboard, large	119.6
5	Fabric-covered, lower-priced, small	84.5
6	Fabric-covered, lower-priced, large	20.0
7	Fabric-covered, higher-priced, small	53.2
8	Fabric-covered, higher-priced, large	57.6
9	Plastic-covered, small	96.7
10	Plastic-covered, large	73.6
11	Leather-covered, small	58.7
12	Leather-covered, large	23.0

The factor contributing chiefly to their breakage was failure of the hardware, particularly the hasps, spot-welded, and the insert type. Frame breaks probably ranked second in cause of failures and low scores. On dropping, the small metal fasteners, which bind the leather edge binding and protect the edges of the cases, work loose. They are generally held by two bifurcated rivets, which are easily loosened from the frame (pinewood) and in turn permit the leather binding to be detached. The joints of the two adjoining faces then separate, and the case is ruined. Some more durable method of fastening the bindings is strongly recommended.

The handles of these fabric-covered cases, as well as those of the leather cases, stood up poorly also in the drop tests. The hollow uprights, which hold the pins supporting the handle, spread on dropping the case on the No. 2 face (handle face) and permit the pin to become dislodged from the holes. The handle then tears off. In some instances the metal, which passes through the frame and which holds the handle plate attached to the frame, loosens because of the dropping, and pulls loose. The metal is quite soft and can be straightened out by hand with little effort.

The highest scores were made by the vulcanized fiberboard and the plastic-coated cases. Both types have proven themselves quite damage-resistant in actual service, according to baggage handlers. The chief fault of the fiberboard was one of distortion of the structure as the test progressed, which would probably allow loss of some small items in actual service if comparable damage were inflicted. This happened as the dropping was made from greater heights and after the bags had been dropped a large number of times. These bags can withstand quite a number of drops before showing frame distortion and are almost indestructible in this test insofar as crushing, tearing, and frame breaks are concerned. The rivets, which form the edge seams and also hold the hardware, are exceptionally hard and resistant toward pulling loose.

The plastic-covered cases received lower scores mainly because of the latches and locks. Being of a different, external-tension snap-over-type construction than the loop snap-over type of the fiberboards, they were more easily misalined. Slightly misalined, they no longer hold, and the entire contents of the cases are spilled. Somewhat less serious is the distortion of the cases due to the nonfit of the tongue and groove edges of the lid and body components caused by severe dropping. As in the case of the fiberboards, this distortion also takes place only after a large number of drops. One peculiar difference was noted between the large and small models. The latter had higher standing lugs (about one-quarter inch taller), a part of the sturdy back hinge, which in several instances caused the surrounding frame wood of the side 4 to fracture when dropped on this face.

The damages observed by dropping the bags seem to correspond closely to the types of damage observed on baggage during the surveys. It is surmised that most damage is inflicted in this manner. The determination of the resistance to damage of a bag on dropping gives a fairly reliable estimate of how well a bag will endure the stresses of average travel. These results on the divided table tester indicate that a bag should be able to amass a score of 50 in order to be classified as satisfactory for service. These points are discussed further in section V, service tests.

Figures 4, B, to 15, B, show typical damage occurring to each test specimen during the drop test. Only the two handle failures in 9, B, and 15, B, were due to the dropping, the others having been damaged on the handle fatigue test.

(d) Puncture Tests

Although the results of the puncture tests indicate that this method may be useful after further development, the data so far obtained are insufficient to justify a recommendation for its inclusion in a commercial standard. Of the 12 bags tested, eight had puncture resistance close to, or beyond the capacity of the instrument, readings of 1,300 to 1,350 inch-ounces being obtained. These specimens were mostly of three-ply veneer construction. Usually the swinging head fractured the specimen but did not completely penetrate it. It is thought that a modified apparatus with perhaps twice the capacity would be useful.

Only the chipboard cases showed very low resistance to puncture, yielding readings of 210- and 227-inch-ounces. One of the fiberboard cases gave a value of 667 inch-ounces, and one of the lower-priced fabric-covered cases punctured at 1,002 inch-ounces. The behavior of these materials in service indicates that a puncture resistance in the neighborhood of 225 inch-ounces is too low, and that a value of 1,300 inch-ounces is satisfactory, but no intermediate fiducial limit can be set with a satisfactory degree of assurance.

V. Service Tests

1. Plan of Tests

In order to compare and correlate laboratory behavior with service performance, a replicate of each of the types tested in the laboratory was sent through regular railroad baggage checking service from Washington, D. C., to various cities and return. Eleven destinations were selected so as to require much handling of the bags because of transfer points en route. The samples were identified by the customary check numbers only, and every effort was made to make the shipment appear as normal as possible in order to prevent any biased handling. The itinerary of the eleven trips was repeated once. On each return, the cases were examined carefully and records kept of their condition. They were then sent over another route. The bags were shipped out alternately locked, half-locked, and unlocked. Some bags had only one lock and were therefore sent locked and unlocked. The total number of miles traveled by the bags was about 12,000, during which they sustained about 24 handlings per round trip. A system for scoring the bags similar to the one used with the divided-table drop tester, was helpful for an evaluation of the bags after the service tests had been completed.

2. Results

Twenty-two round trips resulted in severe damage to six of the 12 specimens. The damage sustained by the six bags was severe enough to classify the bags as failures or as damage-claim luggage. Table 13 lists the types of damage occurring to the cases. In instances where several major damage items are mentioned for one bag, the first item is the primary cause of the damage, the other damage occurring because the bag was left in service to obtain auxiliary information. The trip numbers designate the trip on which the bag failed. The scores represent a numerical comparing system, calculated from the data in a manner similar to that used in the drop tests.

TABLE 13. *Results of service tests*

Bag number	Identification	Score	Number of round trips	Major damage	Minor damage
1	Chipboard, small	2.0	3	Handle failure; large tear	Small tears of covering.
2	Chipboard, large	1.0	2	Large puncture; handle failure	Softening of case; small puncture; small tears.
3	Vulcanized fiberboard, small	20.0	22	None	Lock opened after each trip; abrasion marks plentiful; very slight scuffs.
4	Vulcanized fiberboard, large	23.1	22	do	Lock opened frequently; considerably marked up very slight scuffs.
5	Fabric-covered, lower-priced, small.	21.0	22	do	Leather severely scuffed; separation of edges beneath fabric.
6	Fabric-covered, lower-priced, large.	3.0	5	Handle failure; spot-welded hasp broken.	Severe scuffing of leather binding; small dents in sides.
7	Fabric-covered, higher-priced, small.	21.8	22	None	Separation of edges beneath fabric; moderate scuffing of leather binding; loose rivets.
8	Fabric-covered, higher-priced, large.	13.6	22	Frame break on lid edges 5 and 6; hinge side 4 broken.	Handle plate and pins damaged, loose edges beneath fabric; leather binding scuffed.
9	Plastic-covered, small	20.5	22	None	Scuffing of plastic coating; hinge lugs penetrated coating.
10	Plastic-covered, large	21.9	22	do	Scuffing of plastic coating; temporarily misalined; center latch inoperative.
11	Leather-covered, small	16.2	22	Puncture	Severe overall scuffing; partial hinge break; separation of edges beneath leather.
12	Leather-covered, large	3.9	5	Handle failure	Severe overall scuffing; some edge separation beneath leather.

The types of damage responsible for failures were punctures, one; tears, one; handle failures, three; and frame breaks, one. The additional major types of damage mentioned were not the primary cause of the failure. For example, the large chipboard case failed on the trips because of a large tear. The handle on the same bag broke while it was being returned to the laboratory. The small model of the same material failed primarily because of a broken handle. Substitution of another handle resulted in a tearing of the surface chipboard. The other cases suffering handle failures could not be continued in the tests as the damage was not repairable.

The structurally weak bags broke early in the tests and consequently received lower ratings. The other bags varied in the amount of damage they sustained throughout the tests. The fabric-covered and leather-covered cases were bruised and scarred appreciably. They are, therefore, intermediate between the chipboards and the plastic-covered and vulcanized fiberboards. The latter two types of bags endured the testing admirably and therefore have high scores. Very little happened to them aside from slight scuffing and marring. The small plastic-coated bag, however, was beginning to show the same effect from the high hinge lug as was evidenced in the drop tests.

Larger cases again, as in the drop tests, were more vulnerable to injury than the small bags except for the plastic-covered and vulcanized fiberboard cases. These bags were built to accommodate the heavier loads that would naturally be placed in large size luggage.

The types and extent of damage occurring during the service tests are shown in figures 4, C, to 15, C, in the same order as they appear in table 13.

VI. Conclusions

1. Correlation of Laboratory and Service Tests

The data, though limited in number, indicate that the results of the laboratory tests, especially those pertaining to the handle fatigue and divided-table drop tests, correlate well with the results obtained during the actual service tests. These two laboratory tests duplicate quite well the damage observed during the survey in rail and bus baggage rooms.

It has been shown by the laboratory drop test that the large-sized cases break more frequently than the smaller cases. Table 12 shows this to be true five times out of six based on the average scores of duplicate samples. In service tests, table 13, the same is true four times out of six based on single replicate samples. In the handle fatigue test, in five out of six comparisons of duplicate specimens, the handles of the small bags held up best. The average number of pickups of all the handles of small bags was approximately 35,000 as against approximately 23,000 pickups for all the handles of large bags. In service, four handle breaks were obtained, and three of them were on the large-sized cases.

If size is disregarded and the average scores for the service test samples are compared with scores of the table drop-test method, the rank rating is identical, as is shown in table 14.

TABLE 14. *Correlation between results of service and laboratory tests*

Identification	Service test score	Rank	Laboratory test score	Rank
Vulcanized fiberboard	21.6	1	129.5	1
Plastic-covered	21.2	2	85.2	2
Fabric-covered, higher-priced	17.7	3	55.4	3
Fabric-covered, lower-priced	12.0	4	52.3	4
Leather-covered	10.0	5	40.8	5
Chipboard	1.5	6	27.7	6

The correlation, therefore, between service and laboratory tests, insofar as material, hardware, and construction are involved, is excellent.

No permanent incapacitating effect was produced by externally loading the bags in the laboratory. No truly crushed or flattened cases were had through the service tests. It might be said that the results compare similarly. Only two severe punctures were had in the service testing, one on a bag showing high puncture resistance on the puncture tester, and the other on a bag showing low puncture resistance on the same instrument. The results are, therefore, inconclusive.

2. Recommended Requirements

In view of the data presented, the following recommendations are offered for estimating the performance that might be expected of any given bag when placed in service. The recommendations apply to bags only of the rigid type. The bags should be loaded in accordance with the recommended weighting shown in table 9, except where noted.

A. The empty specimen shall have placed successively on its lid side (side No. 1), its top side (side No. 2), and its end (side No. 5), a 150-pound weight for a time interval of 5 minutes in each position. The surface area of the weight in contact with the bag shall be approximately 5 by 8 inches.

The bag shall show no structural failure, tears, permanent crushing, or irreparable damage.

B. The loaded specimen shall be subjected to the action of an apparatus capable of picking up a bag by the handle and setting it down repeatedly. The apparatus shall pick up and set down the bag at a rate of approximately 37.5 times per minute and shall exert a peak force of 1.8 times gravity when tested against a 50-pound weight.

The bag shall be capable of withstanding 25,000 pickup motions of the machine.

C. The loaded specimen shall be dropped successively on all its faces, edges, and corners from a drop-tester, which meets the requirements outlined in the ASTM Tentative Designation (D775–45T). The initial height of fall shall be 1½ feet and shall be progressively increased by 6-inch increments until the total fall height is 5 feet or until failure occurs. The specimen shall be dropped on each face, edge, and corner, from each height. Records shall be made of the effect of each fall. Each fall shall be evaluated with a numerical score, the value of which shall be commensurate with the damage.

The summation of the scores for all falls shall total 50 or greater to indicate satisfactory resistance to dropping.

D. Some standard form of label or pocket insert card should be placed inside new luggage, as a means of identification of the ownership to help avoid loss of the bag if the baggage check becomes detached along with a faulty handle.

The authors thank officials of the Pennsylvania Railroad for making possible the service tests and for other assistance; the staff of the Washington Terminal for checking out and recalling the samples in service tests; and officials of the New York, New Haven & Hartford Railroad, the American

Airlines, the Pennsylvania Greyhound and Florida Greyhound Bus Lines, the Atlantic Coast Line Railroad, the Seaboard Air Line Railroad, and the Chicago & Northwestern Railroad for permission to make surveys and for their help in conducting them.

The assistance of officers of the National Wooden Box Association in the selection of test procedures and in providing some laboratory facilities is also gratefully acknowledged.

The following members of the staff of the National Bureau of Standards contributed much-appreciated assistance and suggestions: A. S. Best, John Mandel, C. E. Weir, C. W. Mann, and Rene Oehler.

WASHINGTON, February 2, 1949.

U. S. GOVERNMENT PRINTING OFFICE: 1949