A CRITICAL ANALYSIS OF A TEST METHOD FOR MULTIWALL BAGS

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A CRITICAL ANALYSIS OF A TEST METHOD FOR MULTIWALL BAGS

By

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AN ABSTRACT

This study was undertaken to determine the validity and effectiveness of one of the most used and probably the least understood evaluation methods. In addition to the analysis of three variations of the basic method, a comprehensive literature survey was made to determine the extent of information, available to the public, that existed concerning the laboratory or use-testing of paper multiwall shipping sacks. Little has been written that relates to multiwall shipping sacks themselves, and even less on the methods that might be used to evaluate such containers.

Three test methods were investigated. The differences in test methods were in the number of drops per cycle and the surface upon which the bag was dropped. Testing was conducted under rigidly controlled conditions to eliminate all possible variables.

Results obtained indicated that an inner textile bag might be used in such evaluation procedures without masking the effect of the outer paper sack actually being investigated. Differences in the two different bag constructions studied can be detected by the test methods used. Each test type reacts differently toward the bag under test; there is no apparent relationship between test methods.

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I. INTRODUCTION

The Problem

The investigation of an accepted method of testing multiwall shipping sacks to determine the meaning and significance of results obtained when extreme care has been exercised in controlling sample replication and test conditions. To determine the extent of published information available on the specific problem.

Objective

A valid test method for the evaluation of paper multiwall shipping sacks was chosen as the objective of this research investigation. Validity may be ascertained in various ways. One method is that wherein the test procedure and results of a shipping test are analyzed and show either a high positive or negative correlation. Another method would be to assess several types of testing procedures with bags of known and different properties. The successful test would therefore be the one which identified any existing differences, while a test procedure that was not valid would show nothing.

Data from a shipping test controlled to the extent that all variables are noted and kept constant throughout the test is not available. It is to be hoped that some day such a test may be conducted, since data produced would, in the opinion of a group of individuals that could well be classified as experts in the paper shipping sack manufacturing industry (11), be of inestimable value in better fitting the bag to the commodity. It would also result

in producing a bag that would possess the protection desired. Yet it would not have excessive strength properties which tend to increase the cost of the bag unduly.

Without a shipping test criteria, the comparison of different test methods and the selection of the one having the greatest significance is the alternate procedure in selecting a valid test method. This is the approach used in this investigation.

Reasons For Military Interest

The problems of developing suitable shipping containers encountered by the Quartermaster Corps are vastly different from those facing industry. Demands for strength, durability, and inherent protective qualities in the container are:

1. The necessity for long term storage.
2. Shipments to any and all global areas along with weather extremes they may encounter enroute and in storage.
3. The many transfer points of the shipment plus the problem of handling at these points, often by semi-trained personnel or indigent labor.

The military supply problem is considerable. A single combat division requires in excess of 500 tons per day of various supplies, a good portion of which are items of Quartermaster responsibility. A sizeable quantity of the more than 70,000 items of Quartermaster supply are packaged in paper or fiberboard containers of various types.

At the present time a number of techniques exist to evaluate paper, corrugated board, fiberboard and shock absorbing materials. These materials are all manufactured of cellulosic material often in combination with other materials possessing desireable characteristics necessary for the finished product. With respect to laboratory evaluation of cushioning effects, the information is usually readily translatable into terms of field performance. However, for paper or paperboard containers, no exact laboratory techniques exist by which such materials may be adequately evaluated to give information on the ability of the container to withstand the rigors of military usage.

Military usage of a container is considerably different from what might be expected of normal domestic shipments, or even normal export shipments. Quartermaster utilization of a container might typically call for storage for an extended length of time (up to 10 years) and shipment to almost any global area. As such, a container would not only have to withstand normal temperature extremes, but would have to withstand the wet and humid atmosphere of the tropics, the cold and dry atmosphere of the Arctic, the cold and wet atmosphere of Sub-Arctic areas, and the extreme dry of desert conditions. Transportation facilities, more often than not, are different from those encountered in normal usage. Frequently, very crude and primitive methods of transportation to the ultimate point of use might be employed at a time when the container has already withstood more abuse and rough handling than would ever be incurred in normal trade channels. Whereas,

many definitive characteristics such as basis weight, tear, burst, and tensile strength are required in order to permit a container to comply with existing specification requirements, most, if not all, of these tests are but the result of industry custom.

In many cases, development of test requirements through usage and by previous experience of the industry has resulted in highly desireable and valuable methods in product evaluation. However, the paper and paperboard industry acknowledges a lack of application of existing evaluation techniques which are valid and readily reproducible for the determination of suitability of shipping containers.

It is believed that the determination of these unknown properties would be of inestimable monetary savings to the Quartermaster Corps and the Department of Defense. In time of war a great many materials commonly used for container manufacture become scarce, or of greater utility in another end product. While paper also becomes scarce, the nature of the products produced make it somewhat easier to obtain the raw materials required either through expanded salvage facilities or increased utilization of various types of cellulosic materials.

The development of paper products adapted to Armed Forces systems of supply that possess the characteristics of strength, imperviousness, and have the inherent durability of other container materials such as wood and metal is most necessary. In addition, the great advantage of minimum weight plus expendability -- both of which are vital assets in the increasing use of air-delivered supplies--are of vital importance.

Why The Armed Forces Are Different From Other Consumers

In general, the cost of a container becomes a portion of the selling price and is, as a result, passed on to the final consumer. In the attempt to reduce costs, large volume commercial users of commodities normally packed in paper multiwall shipping sacks have frequently made recourse to purchase of these commodities in bulk quantities such as truck load, car load or tank car. As an example, while the small baker will procure sugar and flour by the bag, probably of 100-pound net weight capacity, the large volume producer will frequently obtain flour in truck load or car load lots. The flour, in this instance, is bulk loaded directly in the car and upon arrival at its destination will be "pumped" from the car or truck to the storage bin of the bakery. The sugar may arrive as a highly concentrated syrup, thus saving the cost of evaporation, crystalization and bagging. Similiar analogies can be drawn from the construction industry in their purchases of cement and lime; the paper industry in their purchases of clay, starch and rosin size.

Thus it may be seen that the high volume user of a given commodity will lower his delivered costs by purchasing the items in large "container". On the assumption that a car load of flour might contain as much as eight hundred 100-pound bags and assuming an average cost of a multiwall shipping sack of this size of about $140 per thousand, it is quite evident that the savings in shipping container materials alone amounts to somewhat better than $110.

In addition, considerable savings accrue in that less labor is used, that less product is lost, and probably that more sanitary conditions prevail.

The Quartermaster Corps is the "grocery man" to the Armed Forces and one of the largest purchasers of individual food items in the United States. However, it is forced to purchase these items in the <u>relatively</u> small scale manner that, for example, a restauranteur might use. The paper multiwall shipping sack is used to ship items such as sugar, salt, flour, soap powder, grain products and various chemicals. Because of the volume purchased, a very small cost reduction per unit bag would, over a period of a year, amount to a significant sum. Based on paper production for two given three-month periods in 1949 and 1950 (4), it has been estimated that slightly more than eight per cent of the paper production is used for bags and shipping sacks. Eight per cent of the annual paper production of the United States runs into millions of dollars, and the Army uses its proportionate share of this amount. The annual paper production in the United States for 1956, not including construction paper, wet-machine board, box board or corrugated board, amounted to 13,976,381 tons (12).

II. SPECIFIC FINDINGS APPLICABLE TO THE PROBLEM

A relatively recent study on multiwalls utilized the technique of high speed photography to determine exactly what failed and where failure occurred when bags were tested to destruction on the inclined impact tester. It was noted that the greater percentage of ruptures occurred in the sewn top and bottom seams, but no conclusions were formed as to comparison with shipping failures, nor were the tests conducted with that object in view (10).

The earliest reference to the testing of multiwall shipping sacks was dated September 9, 1920 (7). In December, 1915, the Lime Manufacturers and the Cement Manufacturers associations jointly approached the United States Bureau of Standards concerning the development of specifications for multiwall shipping sacks for their respective products. Because of the war, work on this project was not undertaken until April 1919. Stress and strain curves (probably the first) were developed to show paper stretch and it was concluded that resiliency was probably the best criterion for showing what the paper would do in actual service. It was commented that the stretch results correlated directly with a three foot drop test.

The United States Corp of Engineers has been concerned with the development of a more substantial bag for transporting cement. This work has been reported in a Low Temperature Symposium held in December 1953 (9). Essentially the report deals with high damage rate on cement sacks incurred by the Corps of Engineers in the Aleutian Islands and in the Pacific area during World War II. Similar difficulties were reported from Korea indicating losses of approximately 50 per cent of all cement shipped. Various bags and overslip bags were tested in the attempt to devise a suitable packaging specification. In cooperation with a paper mill and a bag manufacturer a new type of reinforced paper made up into bags of a size to contain 100 pounds of cement are drop tested under low temperature conditions. While sample size is small it is concluded that the mere adding of ply upon ply to the bag does not necessarily improve the performance. It is recognized that rough handling at low temperatures requires a more resilient package. Such is the result of the scrim reinforced polyethylene laminated sheet. It is freely acknowledged that the tests have been restricted to laboratory conditions and that results have been qualitative in nature. "Once correlations have been made with actual arctic conditions, we will be in a better position to evaluate the testing procedures used, as well as the efficiency of the packaging materials involved."(9)

In several papers mention is made of the superiority of sack paper having a high stretch. This is a very reasonable and practical observation. In the past years Cincinnati Industries have developed a bag made with their X-crepe material. Other companies have used pleated creped paper (for the two way stretch) or just plain creped paper. Recently West Virginia Pulp and Paper Company has started to market their "Clupack" paper whose unique property is its "built-in" stretch properties. In this regard it is interesting to note that in 1938 a German report (8) mentioned that brittle paper was unsuitable as bag paper.

Apparently a considerable amount of work has been done in investigating bag papers, various paper tests, and their correlation with shipping hazards. It is unfortunate that this information is not more adaptable for use in this investigation, but such is not the case since the work was done primarily with single walled bags manufactured in small sizes for such items as sugar, coffee, pudding and the like. In actual use, the bags were either enclosed in their individual boxboard containers, or else a quantity of six or more bags was encased in a corrugated shipping container. In one investigation special paper runs were actually made. Here, one of the objectives of primary interest was a study of the stresses to which paper was exposed on bag-making machines (3). It was stated that a high correlation was obtained between the weakening of paper on the bag machines and failure during drop tests. However, here again the results are not applicable to the present problem (loads of 2.2 pounds and drop heights of approximately one foot were used).

In a very fine bit of investigative work (1) drop test data was correlated to shipping test performance. However, here again the bags investigated were of the small capacity, single wall type. It is interesting to note that the statistical procedures used in this investigation are quite similar to the procedures used by the writer. Once again it is quite evident that one of the main criteria for selection of an evaluation media is that of relating it to shipping loss experience. Similar information is found in a report concerning the development of an impact fatigue test. It seems that a good correlation exists between the impact fatigue test on flat sections of paper and the drop test. Unfortunately, from the point of view of the writer, the work was done on items such as pudding bags made to contain various flavored puddings in rather small quantities (4).

The only other reference specifically concerned with the performance and evaluation of multiwall bags is in an article (14) written by the author at an earlier date. A large number of variables was investigated and various conclusions drawn; however, there was no clear-cut relationship between drop test and paper properties. The drop test procedures used in this present investigation have to a large extent been selected by elimination of various procedures used at the time of the previous work, which upon their evaluation, were found to be unsatisfactory in various respects.

This then leaves us with the peculiar situation as it exists today. With such a common place article as a multiwall shipping sack, little information has been found concerning the test or evaluation of such bags. The previous work gives no indication whether the test procedure used can be related directly to transportation losses or whether the test used can actually distinguish between bags of different constructions. It is a well established fact that almost every user and producer of multiwall shipping sacks has developed some sort of test which yields a certain amount of information. ASTM (2) has, in fact, outlined a definite drop test procedure for multiwall bags. To test a series of bags under any given drop test procedure and obtain an average value is relatively meaningless unless that value can relate directly to a shipping loss experience or can be used to show any noteworthy difference between bags made with different strength materials. It is believed desirable, if it can be ascertained that a direct relationship between drop test or paper test and shipping loss experience exists. For the type of bag evaluated, this was well demonstrated in the work of Allen and Paine (1), and this would be what the writer would consider the ultimate goal in proving a suitable test for multiwall paper shipping sacks.

Since data on a shipping test did not exist, and since no data existed to show that any test presently used gave valid results, it was determined that this research investigation should endeavor to find one or more valid test techniques and if this could be done, a useful contribution would have been made.

III. EXPERIMENTAL PROCEDURE

Materials Tested

Contents. It was decided that each bag tested would contain 50 pounds, net weight, of dried beans which were selected as typifying the properties of the various bagged subsistence items and because they are most practical for handling in the laboratory during the testing. Dry white U.S. No. 1 grade beans were used.

Inner Bag. For one of the Pack Varieties, B, the beans were held in a textile inner bag or sack. Such procedure is the normal accepted military requirement for packaging various subsistence items for export. This inner textile bag is best described as: Size 34/31, split from 36 in., 2.95 yd. Osnaburg, $16\frac{1}{2}$ by $30\frac{1}{2}$ in. A.M. (after made), (trim both selvages) R.T. Its tare weight was $4\frac{1}{2}$ oz.

Outer Bag. Pack type B consisted of an inner textile bag with the outer paper multiwall shipping sack. Specification requirements determine the size of the outer paper sack with respect to the inner bag. These requirements are: The relative size of the 50-lb. inner bag and its shipping sack or bag shall be such that the inner bag will assume its full size and shape without placing undue strain on the outer sack or bag. This shall be accomplished by making the shipping sack or bag at least 2 inches greater in circumference and $2\frac{1}{2}$ inches longer than the inner bag.

Based on these requirements for the outer bag for Pack Type B, the paper multiwall shipping sack selected for both pack types was the sewn open-mouth tube bag, 18 by 33 inches.

Two types of sack construction were employed in this investigation to obtain the effects of change in bag style. The sack types were selected from those listed in Federal Specification UU-S-486 and were constructed with six plies. The styles and construction of plies were as follows:

Bag Type A: Style 17X, 60-90AL-60-90AL-60WS-60WS

Bag Type B: Style 19X, 60-90AL-60-60-60-60WS

<u>Preparation Of Shipping Sacks</u>

Two groups of filled sacks were prepared for each bag type. In one group, the beans were loaded in a textile inner bag. When the textile inner bag was used, it was closed by stitching with 6/12 thread. In the other group, the beans were loaded directly into the shipping sack. The paper multiwall shipping sacks were closed using crepe kraft tape of $2\frac{1}{2}$ in. width, cotton filler cord and 6/12 cotton thread. The closure was then dipped in molten wax to a depth of at least $\frac{1}{4}$ in. beyond the kraft tape on the sack body. The wax used was of a micro-crystalline type having a melting point of 140 deg. F. or more, and giving suitable performance at minus 20 deg. F. A total of twenty bags for each Test Type, Bag Type, and Pack Style were evaluated. Statistically, this would be considered a 2 x 3 x 2 experiment, and accordingly, a total of 240 bags were tested. The number of replicates used in this investigation is approximately four times the number of specimens usually used.

A moisture determination was made on a specimen cut from the bag after the failure point was reached in the drop test. Specimens were dried in an oven with forced air circulation for a period of twenty four hours at a temperature of 104 degrees Centigrade. They were weighed after cooling in a dessicator for 30 minutes. The moisture content reported in the tabulation of the test data was computed using the approved ASTM procedure (2).

Test Method

All sacks were placed in the testing atmosphere of 73 degrees F. and 50 per cent relative humidity for about ten days prior to testing.

Each face of the sack was numbered with the front of the sack without the glued seam up, as follows: The top sewn seam was identified as 1, the bottom or manufacturer's sewn seam as 2, the right side as 3, the left side as 4, the front face without the glued seam as 5 and the back face with the glued seam as 6.

After the conditioning period, the sacks were subjected to three varieties of drop cycles. The cycles were as follows:

Test Type I: Two drops per cycle

1. Drop on top sewn seam
2. Drop on bottom sewn seam

Test Type II: Four drops per cycle

1. Drop on top sewn seam
2. Drop on bottom sewn seam
3. Drop on right side
4. Drop on left side

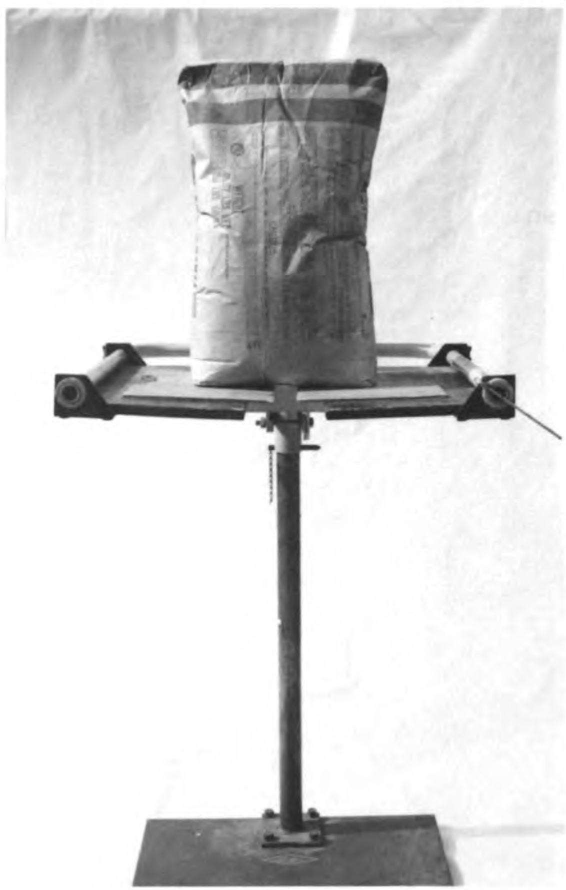
Test Type III: Six drops per cycle

1. Drop on top sewn seam
2. Drop on bottom sewn seam
3. Drop on right side
4. Drop on left side
5. Drop on front face
6. Drop on back face

All test specimens were dropped from a constant height of four feet. An Acme Drop Tester was used for making the drops. Figure 1.a shows a bag in position ready for the drop on the bottom end, or butt. Figure 1.b represents a typical fall on the bottom end. It should be noted that the bag used in these figures was of pasted top and bottom construction, while the bags actually used in the testing were of sewn ends. Regardless of the bag construction or appearance, the dropping techniques used were as shown. Each sack was dropped until failure occurred. Failure was defined as exposure of the inner textile bag or spillage of contents. The drops to failure were the actual number of drops without respect to the type of test cycle used.

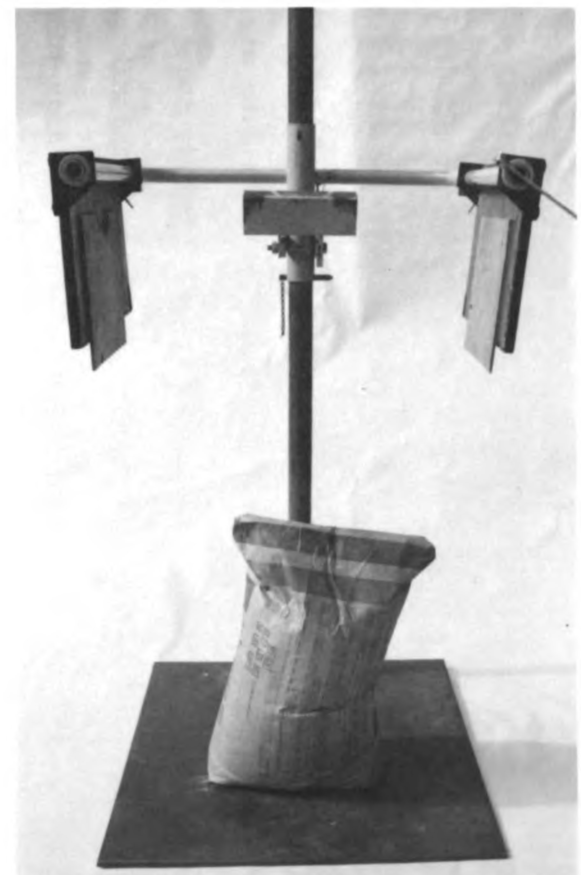
Figure 1

The Drop Test Apparatus Used



1. a

Bag in position for a butt drop



1. b

A typical butt drop

IV. ANALYSIS OF TEST DATA

Drop Test Results

The individual drop test results for each bag tested along with the moisture content of each bag are shown in Tables I thru VI. The type of tear observed at the time of failure is also noted. Even with the ten day conditioning procedure used prior to testing the bags, the moisture content of the paper varied. One of the sources of this variation is the asphalt barrier material present in one or two of the plies, dependent upon bag type. Past experience has indicated that frequently a small amount of material is present that volatilizes at or below the temperatures normally used for moisture determination analyses, and as a result, biased values for moisture content might be obtained.

A consolidation of the test data into a single table giving the average values for all test variables was considered to be the first step in an efficient analysis of the data. Table VII entitled, "Summary of Test Results", contains the summation of all test variables.

TABLE I

Drop Test Results, Moisture Content Values, With Averages

Test Method I   Bag Type A   Pack Varieties A and B

PACK A			PACK B		
Drops to Failure	Type of Tear	Moisture Content %	Drops to Failure	Type of Tear	Moisture Content %
26	V	6.16	15	V	5.50
18	V	7.38	1	V	6.28
28	V	6.84	11	V	6.64
9	V	6.09	15	V	5.43
5	V	6.18	3	V	4.55
19	V	6.56	17	V	5.72
15	V	5.75	18	V	8.11
25	V	6.39	17	V	5.90
15	V	6.70	33	V	4.55
20	V	5.66	9	V	5.75
21	V	6.30	25	V	6.14
4	V	6.06	15	V	5.65
8	V	7.28	18	V	5.65
11	V	6.35	9	V	6.38
17	V	5.82	46	V	6.54
24	V	6.07	32	V	5.79
16	V	6.06	35	V	7.67
7	V	6.60	11	V	7.12
37	V	4.78	9	V	5.93
10	V	5.51	14	V	6.55
16.75	...	6.23	17.65	...	6.09

Type of Tear: V, indicates vertical tear on one of bag faces.

S, indicates tear on top or bottom sewn seam.

TABLE II

Drop Test Results, Moisture Content Values, With Averages

Test Method II   Bag Type A   Pack Varieties A and B

PACK A			PACK B		
Drops to Failure	Type of Tear	Moisture Content %	Drops to Failure	Type of Tear	Moisture Content %
13	S	6.71	17	V	6.49
17	S	4.60	17	V	5.70
14	V	5.90	4	S	6.35
7	S	6.52	25	V	6.07
22	V	4.33	14	S	5.53
17	V	8.09	17	V	6.33
22	V	7.14	19	S	4.00
27	S	6.64	5	V	5.87
20	S	6.70	11	S	6.13
11	S	6.15	12	S	8.81
13	V	9.57	15	S	6.20
8	S	6.96	15	S	6.04
12	S	7.27	29	V	7.28
12	S	5.76	5	V	5.00
26	V	8.34	13	V	5.57
15	S	8.14	30	V	6.83
8	S	8.05	8	S	5.84
12	S	7.77	40	S	7.09
4	S	5.93	17	V	5.54
14	V	5.63	13	V	4.84
14.70	...	6.81	16.30	...	6.08

Type of Tear: V, indicates vertical tear on one of bag faces.

S, indicates tear on top or bottom sewn seam.

TABLE III

Drop Test Results, Moisture Content Values, With Averages

Test Method III Bag Type A Pack Varieties A and B

PACK A			PACK B		
Drops to Failure	Type of Tear	Moisture Content %	Drops to Failure	Type of Tear	Moisture Content %
14	S	5.50	18	S	9.70
5	V	6.20	31	V	6.65
18	V	5.70	45	V	6.28
5	S	5.90	22	S	7.25
15	S	5.70	41	S	5.70
9	V	5.40	9	S	7.55
5	V	5.70	16	S	7.15
15	S	6.50	5	S	6.76
12	V	6.30	10	S	6.50
11	V	5.60	11	S	5.05
11	V	6.70	67	V	4.02
28	S	6.40	56	V	4.64
21	S	6.10	1	V	5.31
21	S	6.30	19	V	5.85
12	S	6.80	22	S	5.05
17	V	5.40	44	V	6.19
5	S	5.50	39	S	4.97
21	S	6.60	20	V	4.67
14	S	5.84	21	V	5.90
13	V	6.20	50	V	4.87
13.60	...	6.02	27.35	...	6.00

Type of Tear: V, indicates vertical tear on one of bag faces.

S, indicates tear on top or bottom sewn seam.

TABLE IV

Drop Test Results, Moisture Content Values, With Averages

Test Method I   Bag Type B   Pack Varieties A and B

PACK A			PACK B		
Drops to Failure	Type of Tear	Moisture Content %	Drops to Failure	Type of Tear	Moisture Content %
9	V	6.12	11	V	5.20
19	V	5.90	30	V	5.90
15	V	5.65	40	V	8.40
15	V	6.70	29	V	7.70
11	V	5.75	33	V	5.70
6	V	6.84	18	V	7.50
19	V	7.28	15	V	6.00
17	V	6.87	13	V	6.30
27	V	6.25	24	V	6.10
19	V	6.69	27	V	5.10
23	V	5.91	18	V	5.30
21	V	6.75	14	V	5.60
16	V	6.31	15	V	7.50
14	V	6.53	20	V	6.20
10	V	5.52	26	V	5.70
3	V	6.90	23	S	5.30
19	V	6.93	49	V	5.10
22	V	6.93	29	V	6.90
25	V	6.15	28	V	6.70
16	V	4.85	19	V	5.30
16.30	...	6.34	24.05	...	6.18

Type of Tear: V, indicates vertical tear on one of bag faces.

S, indicates tear on top or bottom sewn seam.

TABLE V

Drop Test Results, Moisture Content Values, With Averages

Test Method II   Bag Type B   Pack Varieties A and B

PACK A			PACK B		
Drops to Failure	Type of Tear	Moisture Content %	Drops to Failure	Type of Tear	Moisture Content %
26	V	8.24	17	S	6.00
15	S	5.00	23	V	5.70
33	V	4.90	16	V	6.70
4	V	4.90	15	V	6.00
13	V	5.10	10	S	6.20
11	V	4.70	15	V	6.10
19	V	3.90	10	S	5.00
7	V	3.50	29	V	5.70
7	V	3.90	12	S	6.80
13	V	4.60	16	S	5.80
21	V	4.70	21	S	4.70
7	V	4.30	9	S	6.30
15	V	3.60	11	V	5.80
11	V	4.40	12	S	6.00
13	V	4.70	9	S	6.10
7	V	5.50	9	S	5.40
4	V	5.40	22	S	4.50
9	V	4.40	14	S	5.40
14	V	4.90	21	S	6.10
12	V	5.40	13	S	4.90
13.05	...	4.80	15.20	...	5.74

Type of Tear: V, indicates vertical tear on one of bag faces.

S, indicates tear on top or bottom sewn seam.

TABLE VI

Drop Test Results, Moisture Content Values, With Averages

Test Method III Bag Type B Pack Varieties A and B

PACK A			PACK B		
Drops to Failure	Type of Tear	Moisture Content %	Drops to Failure	Type of Tear	Moisture Content %
25	V	6.36	20	V	8.20
50	V	6.26	40	S	8.07
22	S	7.00	57	S	7.91
39	S	6.52	45	S	8.25
32	V	6.48	40	V	8.60
55	V	5.97	49	V	7.83
44	V	6.40	46	S	7.81
55	V	6.01	38	V	7.90
44	V	6.24	86	V	7.50
38	V	6.14	20	V	8.42
20	V	5.59	62	V	7.73
38	V	6.14	68	V	7.60
48	V	6.18	18	V	4.70
28	S	5.91	36	V	6.30
31	S	6.17	29	V	6.10
43	V	5.57	61	V	6.70
25	V	7.29	35	V	6.00
7	S	4.83	57	V	5.50
31	V	7.29	23	V	6.10
37	V	6.97	35	V	6.50
35.60	...	6.27	43.25	...	7.19

Type of Tear: V, indicates vertical tear on one of bag faces.

S, indicates tear on top or bottom sewn seam.

TABLE VII

Summary Of Test Results

Average Number Of Drops To Failure

Bag Type Average Drop Value	Test I Pack A	Test I Pack B	Test II Pack A	Test II Pack B	Test III Pack A	Test III Pack B	All Three Tests Packs A + B
A, Actual	16.75	17.65	14.70	16.30	13.60	27.35	17.73
A, Coded	3.75	4.65	1.70	3.30	0.60	14.35	4.73
B, Actual	16.30	24.05	13.05	15.20	35.60	43.25	24.58
B, Coded	3.30	11.05	0.05	2.20	22.60	30.25	11.58
Averages A+B							
Actual	16.53	20.85	13.88	15.75	24.60	35.30	21.15
Coded	3.53	7.85	0.88	2.75	11.60	22.30	8.15

Table VII lists the three test types, two types of bags, and two pack varieties. These have all been described in detail in the section on experimental procedure. In the statistical analyses made, techniques and procedures found in references (5), (6), and (13) have been used. Tables VIII thru XII summarize the statistical analyses of these data.

An analysis of variance was carried out on the test results and it was found that the large mean square pertaining to the interaction bag x test was so large that none of the test averages showed significance. On examining the material further it was seen that the variances could not be pooled to form an error term and hence the analysis of variance could not be used for testing significant differences between averages (see table VIII). Since the interaction of Bag Style x Test Type was of such a magnitude, all other interactions and the residual were discarded and the value of the mean square of this interaction was used as the error term for calculation of the F value. Using this interaction mean square as the error term resulted in finding no significance between any of the averages of the main effects namely Test Type, Bag Style, or Pack Type. While the results were not significant, the trend of the analysis indicated that of the three main effects the test type was of most importance followed by the bag style and finally by the pack variety. The three other interactions were of no significance and are not worth mentioning while the interaction used for the error term indicates that for reasons unknown each

TABLE VIII.

Analysis of Variance

All Test Methods   All Bag Types   All Pack Variations

Source Of Variation	Sum Of Squares	Degrees Of Freedom	Mean Square
Total	46615	239	
Test Type	9893	2	4946
Bag Type	2815	1	2815
Pack Type	1904	1	1904
Bag x Test	4582	2	2291
Test x Pack	830	2	415
Pack x Bag	3	1	3
Test x Bag x Pack	419	2	210
Residual	26168	228	115

F (2,2,.05) = 19.00

bag variety reacts differently toward each test type.

Although significance was not obtained in the analysis of variance on all test data, it seemed probable that division of the data by Pack Type might yield interesting results. Accordingly, this separation was made (see Tables IX and X). It is readily apparent that with Pack Type A the interaction of bag x test is so large that it completely overshadows the main effects. Hence, no significance between various averages was obtained from the test results for all combinations of bag style with test type. With Pack Type B we again have a large interaction, so large in fact that it will become the error term, and as a result we again have no significant differences between the various averages. However, the main effects are of much greater magnitude for Pack Type B than they were for Pack Type A.

Only one technique remained to be checked. The results obtained with Pack Type A have been shown to yield no significant differences between the mean square of the three variables examined by analysis of variance. The evaluation of Pack Type B seemed to show promise. It was therefore decided to compare the variances for each of the different test types for this pack variety. These data are presented in Table XI. The variances for each test type were compared with each other in order to test the null hypothesis that all test results were really from the same universe of test results. Accordingly, F values were calculated, which upon comparison to standard tables show significant differences between the three test

TABLE IX.

Analysis of Variance for Pack Type A

All Test Methods All Bag Types

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square
Total	14755	119	
Test Type	2497	2	1249
Bag Type	1320	1	1320
Test x Bag	3549	2	1775
Residual	7389	114	65

F (2,2,.05) = 19.00

TABLE X.

Analysis of Variance for Pack Type B

All Test Methods All Bag Types

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square
Total	29956	119	
Test Type	8227	2	4114
Bag Type	1498	1	1498
Test x Bag	1452	2	726
Residual	18779	114	165

F (2,2,.05) = 19.00

type variances, that is test results for each test type were different at the 1% level. The same type of analysis was carried out for Pack Type A and similar results were obtained. These results are shown in Table XII.

On examining the data in detail it was found that the coded averages 22.30, 2.75, and 7.85 were so different that there appeared to be a significant difference between the highest average and the lowest average and perhaps between the highest average and the next to the highest average. A t-test was determined, comparing the highest average with the lowest average where the variances were not the same and it was found that the highest average was significantly different at the 1% level from the lowest average. It was found by a similar test that the highest average 22.30 was significantly larger than the next to the lowest 7.85. It was also found that the next to the highest average was significantly different from the lowest average. These averages are shown in Table XI together with the various t-values for the coded averages.

Since the interaction was so high in the analysis of variance no significance for the test averages could be obtained. However, there are significant differences between the cell averages as seen in Table VII. In particular, the averages for Pack A and Pack B of Bag Styles A for Test III are certainly significantly different, and also for Pack A and Pack B for Bag Style B for Test I. Other differences are also apparent. This additional statistical comparison is quite important, since information obtained from the analysis of variance would definitely tend to indicate that no significance could

TABLE XI

Comparisons Between Variance of the Means

for Pack Type B and Both Bag Styles

STATISTIC	TEST TYPE I	II	III
Mean number of drops to failure *	20.85	15.75	35.50
Coded Mean Value	7.85	2.75	22.30
Variance	117.77	54.95	384.41
Standard Deviation	10.86	7.41	19.60
Standard Deviation of the Mean	1.71	1.17	3.10
Number of Replicates	40	40	40

* Average number of drops to failure without regard to the cycle used. Cycle was a function of the Test Type.

COMPARISON TESTS	AS CALCULATED t-Score	F-Value
Test Type I and II	2.46	2.14
Test Type I and III	4.08	3.26
Test Type II and III	5.90	7.00

$F\ (39,39,.01) = 2.11$ $\quad$ $t\ (.01,78) = 2.36$

TABLE XII

Comparisons Between Variance of the Means

for Pack Type A and Both Bag Styles

STATISTIC	TEST TYPE I	TEST TYPE II	TEST TYPE III
Mean number of drops to failure *	16.53	13.88	24.60
Coded Mean Value	3.53	0.88	11.60
Variance	51.00	45.28	218.00
Standard Deviation	7.14	6.73	14.76
Standard Deviation of the Mean	1.29	1.06	2.33
Number of Replicates	40	40	40

* Average number of drops to failure without regard to the cycle used. Cycle was a function of the Test Type.

COMPARISON TESTS	AS CALCULATED t-Score	AS CALCULATED F-Value
Test Type I and II	1.71	1.12
Test Type I and III	3.11	4.26
Test Type II and III	4.18	4.82

$F\ (39,39,.05) = 1.69$ $\quad t\ (.05,78) = 1.66$

$F\ (39,39,.01) = 2.11$ $\quad t\ (.01,78) = 2.36$

be attached to the Pack Type, and as a result, erroneous conclusions could be deduced that would be instrumental in the selection of the type of testing procedure.

V. CONCLUSIONS

1. Differences in the sack constructions used in this investigation are not made apparent by the test techniques used, although from a cost, construction, and usage view point these differences are quite apparent.

2. The range of test values obtained is very wide, and this attribute has been most instrumental in producing the nonsignificance to the test variables.

3. No relationship exists between the three test methods examined. Each reacts differently with the subject under test. The interaction effects of Test Type, Bag Type and Pack Variety are so large as to eliminate any significance from any of the three test methods examined, at least to the extent of the Pack variations and Bag types used in these experiments.

4. Since all three of the tests treat the test subject differently, and none show differences between test subjects, the choice of the test method may be left to the decision of the researcher. It is the opinion of the writer that in view of this, Test Method II is to be preferred since fewer drops are required to cause failure and the standard deviation between replicates is less than for the other test methods.

5. A sufficient number of failures occurred on the sewn seam to indicate that a definite weakness exists at that portion of sewn open mouth bags. An improved type of closure is desirable.

VI. SUGGESTIONS FOR FURTHER WORK

Repetition of one-half of the experimental procedures using a paper multiwall shipping sack of the same size, with the same test load, but of a construction 60-90AL-60-60WS, should certainly determine whether or not the drop test technique is actually a meaningful test in that if no positive significance between bag styles is obtained with bags having such gross differences, then the test is most insensitive and should be discarded.

LIST OF REFERENCES

1. Allen, R.J.L. and Paine, F.A. "Transport Trials and Laboratory Tests on Food Containers. I - Lined Kraft-paper Bags," J. Sci. Food Agric., 2, #5:208 (May 1951).

2. American Society for Testing Materials. ASTM Standards on Paper and Paper Products and Shipping Containers. Philadelphia: American Society for Testing Materials, 1955.

3. Corte, Heinz. "Mechanical Properties of Paper Bags," Verpakungs Rundschau No. 8: Suppl. 49-55 (August 1955).

4. Couch, R. de S., and Muldoon, T.J. "Impact-Fatigue Test for Paper," Modern Packaging, Vol. 24, #4, (Dec. 1950).

5. Dixon, W.J. and Massey, F.J. Introduction to Statistical Analysis. New York: McGraw-Hill Book Co., Inc., 1957.

6. Goulden, C.H. Methods of Statistical Analysis. New York: John Wiley & Sons, Inc., 1956.

7. Houston, P.L. "Testing Lime and Cement Bag Paper," Pulp and Paper Magazine of Canada, 18:947 (Sept. 9, 1920).

8. Lange, Wilhelm, "Demands on the Nature and Properties of Paper for Bags," Wochbl. Papierfabr., Vol. 69, #45:933.

9. National Academy of Sciences. Low Temperature Test Methods and Standards for Containers.

10. O'Conner, D.J., "Filled Multiwalls in Transit - High Speed Photo Study," Industrial Packaging, Vol. 1, #7:23 (July 1955).

11. Quartermaster Corps Industry Advisory Committee on Multiwall Bags. Unpublished committee meeting minutes.

12. U.S. Dept. of Commerce, Bureau of the Census, Statistical Abstract for 1958. Washington: U.S. Govt. Printing Office.

13. Walker, H.M. and Lev, J., Statistical Inference. New York: Henry Holt & Co., 1953.

14. Younger, J.O. and Sargeant, J.A. "Evaluating Multiwall Bags," Modern Packaging, Vol. 28, #3:157 (Nov. 1954).

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