5 26 69

John Herring
Plant Engineer
Pacific SW Region
American Cem ent Corp.

Dear John;

Thank you for sending to me a copy of your report of the cement bags study.

You have done an excellent job of accumulating and presenting important knowledge in a decision framework.

Best regards to you and your associates,

Larry Miles

PACIFIC SOUTHWEST REGION — AMERICAN CEMENT CORP., 1500 RUBIDOUX BLVD., P.O. BOX 832, RIVERSIDE, CALIF. 92502 • (714) 683-3660

May 15, 1969

Mr. L. D. Miles
Miles Associates
P. O. Box 4740
Washington, D. C. 20020

Dear Mr. Miles:

Enclosed is the final report on bags submitted by our Packhouse Value Engineering Team.

We did receive word back that the Sales Department took a good look at the draft of this report.

We would appreciate any comments you might have on this study.

Sincerely yours,

Pacific Southwest Region
AMERICAN CEMENT CORPORATION

J. A. Herring
Plant Engineer

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enc.

cc: CWBush
RCEntorf
File

INTER-OFFICE CORRESPONDENCE

RIVERSIDE DIVISION ≡ AMERICAN CEMENT CORPORATION

May 14, 1969

To: R. C. Entorf

From: J. A. Herring

Subject: Packhouse Value Engineering Study
Cement Bags Project 2-345/V2-25

Attached is the bag section of the Packhouse Value Engineering Study. Though there are no actual recommendations in the report, the recommendation is made here that we take a very close look at the moisture barrier, and at embossing.

Though this report completes the study, the project will remain open and as recommendations of this study are implemented they will be handled as subsections of this project.

For the Study Team,

J. A. Herring, Coordinator

JAH 11
attachments (3 pages)

cc:
MWBlack
CWBush
RSFlynt
PGFryer
WAFranz
COHall
JLHendrickson
*REHyche
AHLogan
MMertens
WEMitze
NPeckham
RBPeterson
GMPetzar
BGPreston
JPRoberts
RWSearle
EMShull
NWShurrager
MDSmith
*WRTrudgen
JWarren
GAWood
File 2-345
V2-25
*LDMiles
Miles Assoc.

*article, "Water Vapor Transmission Through Sacks and Sack Papers" attached

PACKHOUSE VALUE ENGINEERING STUDY
BAG SECTION OF REPORT

The following is the report on the bag section of the Packhouse Value Engineering Study.

Due to the impact on sales of any variation in our packaging and as there were no salesmen on our Committee this report makes no recommendations. This study developed and presents information which controls bag cost so that aesthetic factors can receive current evaluation.

Based on the 1969 forecast this year we will spend approximately $550,000 for bags, not counting the export order. A functional breakdown of this cost follows:

1. Basic package-----------------------------------$340,000
2. Additional strength of package-------------------$ 69,000
3. Embossing for antiskid properties----------------$ 12,000
4. Moisture barrier---------------------------------$104,000
5. One-color identification-------------------------$ 23,000
6. Second color for identification------------------$ 1,400
7. Semi-bleached outside ply for sales promotion-----$ 7,000
8. 4th ply added strength (white only)---------------$ 8,000
9. Larger size bag (plastic and gun plastic)--------$ 10,300

1. Basic package--$340,000/year

The cost of the basic package is based on a two-ply bag, both plys being 1/70 base weight standard Kraft with filling valve. This, in the Committee's opinion, is the least expensive package capable of containing cement.

2. Extra strength---$ 69,000/year

Going to a three-ply bag with the two inner layers of 1/50 base weight and an outer layer of 1/60 base weight all-extensible paper for added strength. Of the $69,000 $36,150 is the cost of the extra 20-base weight which gives added strength against tearing. The remaining $32,600 is for the extensible paper which gives added strength against inside pressure and impact.

3. Embossing--$ 12,000/year

Bags were originally embossed to provide antiskid properties, with the cost assumed by the bag supplier. Then the supplier decided to pass along the above additional cost to us. Embossing raises the average slip angle of the extensible paper sack from 32.3° to 33.5°. Since that time, however, the entire surface of the outer bag is treated to give it antiskid properties at no added cost. This treatment gives extensible paper an average slip angle of 37.0°. The average slip angle of extensible paper, embossed, and treated is 38.0°. It is accordingly suggested that embossing and its $11,000 annual cost be given close scrutiny.

4. Moisture barrier---$104,000/year

Approximately two years ago we added this moisture barrier to our bag cost we are told essentially because our competition did and it was then considered essential in order to avoid sales loss.

It was found however that the bags couldn't be filled - blew up like balloons - so to

to page 2

facilitate filling we found it necessary to have openings lanced through the bag, approximately 800 on 1" centers over its entire surface, which the supplier did without passing on added charges to us.

Much of the extra cost which now goes into this expensive barrier is thrown away by the 800 holes. Reference is made to paper by R. L. Reeves & W. E. Kilgore entitled, "Water Vapor Transmission Through Sacks and Papers".

We still occasionally have cement returned to us because of moisture penetration. More prudent use of the $104,000 may call for different action. Some feasible alternatives to our present course follow:

Alternative I — The use of minipoly coating would reduce cost by $22,000/year and after similar punching of holes probably provide essentially the same barrier.

Alternative II — Ship cement in bags without barrier during the dry summer months, May through September. We ship 49% of our bags in these five months which would make a saving of $63,700/year.

5. One-color identification-- ---$ 23,000/year

This cost seems to be well worth the expense as some means of rapid identification of types is necessary and with our present method we also receive an advertising use factor from this expense.

6. Second color for identification--$ 1,400/year

All but $200 of this cost is for the second color on our white cement bag. The function here is to provide a distinctive package to promote sales of white cement. In the case of the $200 which is the second color on our rapid takeup gun plastic sacks the function is identification which could be taken care of by using a distinctive shade of green from the green of our regular gun plastic. Though the savings here probably do not warrant a change due to the low volume shipped this second color cost should be taken into account on future new products so that we do not get caught with a two-color package on a high-volume line.

7. Semi-bleached outside ply--$ 7,000/year

The function of this item is to provide a distinctive package to promote the sale of white cement.

8. Fourth ply added strength for white cement bags-------------------------$ 8,000/year

The function of this extra strength is prestige. We have a more expensive prestige product so we put it in a more expensive bag. Does the customer know this is a stronger bag?

9. Larger size bags for plastic and gun plastic----------------------------$ 10,300/year

The function of the larger size is to contain the product; plastic cement is less dense than regular and gun plastic has the asbestos added to it.

JAH 11
attachments 3

J. A. Herring, Coordinator

FUNCTIONAL BREAKDOWN OF OUR BAG COSTS

FUNCTION	DESCRIPTION OF ITEM	COST PER MILLION BAGS
Basic package	Inside ply 1/70 base weight standard Kraft Outside ply 1/70 base weight standard Kraft (including fill valve, etc.)	$ 59,330
Strength increase*	Inside ply 1/50 base weight extensible Second ply 1/50 base weight extensible Kraft $6,320 Outside ply 1/60 base weight extensible $5,700	$ 12,020
Antiskid	Antiskid coating (outside ply)	-0-
Antiskid	Embossed (outside ply)	$ 2,000
Moisture barrier	.75 mil film laminated to 2nd layer	$ 18,100
Identification	One-color printing	$ 3,950
Advertising	Second color printing (white only)	$ 1,400
	Semi-bleached outside ply (white only)	$ 8,150
Larger capacity	Gun plastic	$ 5,400
	Plastic	$ 4,900
*Prestige	White only 4-ply 1/50 base weight extensible (add)	$ 9,650

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SHIPMENTS BY YEAR IN MILLIONS OF SACKS
(not including export order)

Year	Regular	Block	Plastic	Gun Plastic	XGun Plastic	White	Total
1967	2.55	.09	1.55	.242	.072	.820	5.324
1968	1.98	.104	1.67	.289	.099	.869	5.012
1969 Forecast	2.352	.108	1.920	.340	.140	.864	5.724

CALCULATIONS OF YEARLY COSTS
(based on 1969 forecast)

Function		Cost/million	Million/year	Cost 1969
Basic Package		59,330	5.724	339,600
Strength		12,020	5.724	68,800
Antiskid		2,000	5.724	11,500
Moisture Barrier		18,100	5.724	103,600
Identification (1 color)		3,950	5.724	22,600
Advertising (white & XGun)		1,400	1.004	1,400
Semi-bleached (white only)		8,150	.864	7,000
White only 4-ply bag		9,650	.864	8,000
Larger Sacks				
	Gun	11,150	.480	5,400
	Plastic	2,550	1.920	4,900
				573,000

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INFORMATION SUPPLIED BY INTERNATIONAL PAPER CO.

Slide angles of various Kraft papers with and without processing for antiskid characteristics:

	PAPER	AVERAGE SLIDE ANGLE
50#	Standard Kraft	30.0°
50#	Extensible	32.3°
50#	Embossed extensible	33.5°
50#	Standard Kraft w/antiskid coating	36.0°
50#	Extensible w/antiskid coating	37.0°
50#	Embossed extensible w/antiskid	38.0°

Average moisture vapor transmission rates for most of the commonly used barrier papers:

30 - 30 - 30 Asphalt	2.5
MP 100	2.4
MP 150	1.6
MP 200	1.1
MP 300	.8
MP 400	.6
.75 mil film	.95

These figures constitute the maximum average water vapor permeability at 70% R.H., 100° F. g/100 in. 2/24 hrs.

JAH 11
5-1-69

R. L. REEVES
and W. E. KILGORE

Water Vapor Transmission Through Sacks and Sack Papers

Water vapor transmission through sacks and sack papers is often of paramount importance to the multiwall bag manufacturer and the bag purchaser for obvious reasons. Many dissertations have been written concerning water vapor permeation through unconverted coated and laminated sack papers, unattached plastic films, and laminated and coated plastic combinations. There is a significant difference between water vapor transmission rates of an unconverted barrier vs. a converted barrier. Often the ability of a coating to withstand creasing and abrasion, plus stitching and gluing of a multiwall bag, is a more critical factor as far as successfully packaging the product than moisture penetration through the barrier ply. This paper is primarily concerned with moisture penetration through barrier plies at "vulnerable areas" of a gusseted multiwall bag, such as glue seams, closure ends, and gusset creases tested at 100°F and 95% RH, plus a means for determining the moisture protection necessary for packaging a given product.

A RELIABLE means for determining water vapor transmission rates through converted papers and multiwall sacks requires production machine-made samples, filled with the material actually packaged and stored under specified conditions until a constant rate of moisture gain is recorded, which usually requires approximately 15 days' storage. It has been found that moisture penetration, as recorded by this method, tends to correlate more closely with field performance of multiwall bags than any other means of measuring water vapor transmission rates. This is attributed to two reasons: (1) The test specimens have almost all the characteristics of the commercial bag. (2) The product tested is the actual material packaged. Thus, any side reactions that may occur in the field often occur under the accelerated storage conditions, and since normally several different constructions are tested, comparative conclusions may be drawn.

No satisfactory method has been devised for assimilating or duplicating the creasing, breaking, and frictional drag that the multiwall bag tuber's former blades impart to barrier plies situated as the inner (barrier side facing inward) or outside ply (coated side facing outward). The extent of damage to a barrier ply may be great or little, and depends on the overall bag construction, lubricants used on the sheet (when positioned as the inner ply), type of fi... ply position, draw rolls, web tension, etc. Because of these variables, the present practice of evaluating a barrier ply by its water vapor transmission (WVT) test in the roll, so to speak, rather than by its WVT rating after the stresses and strains of converting, is not completely satisfactory for projecting field performance of its finished bag.

By definition water vapor transmission is the rate of water vapor permeation through a barrier under specified conditions of temperature, relative humidity, unit area and time. TAPPI test conditions (T 448 m-49) specify 73°F and 50% RH on one side of the sample and less than 5% on the other. General Foods WVT test method calls for 92% RH on one side of the sample and less than 5% on the other, at 100°F. Most investigators accept the basic theory of the water vapor penetration mechanism as that of activated diffusion, with the vapor pressure differential between the two different relative humidities being the driving force across the test specimen. In gusseted multiwall sewn bags, the passage of moisture through threads, unprotected areas, and sheet deformations adds significantly to the rate of penetration through the bag as a whole.

Methods commonly used in designing multiwall bags for products requiring moisture protection are trial and error, plus experience, which often involves lengthy warehouse storage tests of two or more constructions, and trial production order shipments. Generally, these methods are quite conclusive in determining a satisfactory bag design and construction. However, they are expensive and time consuming, plus the fact that a bag developed during one season and in one climate may not necessarily be expected to perform in the same manner during another season, or in another climate. Thus, for any packaging application, the most severe environmental conditions encountered which are critical to the product and package components, plus the amount of moisture gain or loss through the barrier, govern the degree of resistance to water vapor penetration. This concept determines the test conditions of bags designed by the accelerated storage method.

CONVERTING

Bag types most commonly used for packaging highly hygroscopic products are sewn gusseted open mouth, sewn open (gusseted) mouth (flat tubed), or sewn valve.

The problem of moisture penetration through the sewn open mouth (flat tube) has been practically eliminated as far as the manufacturing difficulties are concerned, by placing a seamless polyethylene flat tube as the inner ply and heat sealing (thermal or dielectric) the tube above the sewing line through the kraft side walls. The bag user seals the top end likewise, after filling. Many carload shipments of bags filled with a highly hygroscopic material have proved this feature to be most satisfactory in field performance.

Since films of narrow gage (1 to 3 mils offer equal WVT resistance over equivalent gage films coated on kraft paper, it would be desirable theoretically to package all products requiring a significant degree of moisture protection in bags possessing a free film inner ply of polyethylene. Thus, the inner ply could be sealed and the greatest protection potential could be realized due to the optimum closure as mentioned above. However, because of converting difficulties at this time, neither lightweight polyethylene sheeting nor gusseted polyethylene tubing can be uniformly and economically placed as the inner ply of a gusseted bag by a multiwall bag tuber. Gusseted bags are by far the more desirable from the standpoint of filled bag appearance and ease of palletizing. Therefore, as a rule, polycoated paper is used as the barrier ply in gusseted type bags.

Attention is drawn to the gusset creases (Fig. 2), for here cracking and abrasion of the coating have caused extensive and costly bag failures in warehouse storage.

R. L. REEVES, Supervisor of Technical Sales Service, and W. E. KILGORE, Laboratory Technician, International Paper Co., Bagpak Division, Camden, Ark.

Table I.—Water Vapor Transmission Rates on the Converted Bag
g/m²/24 hr (90–95% RH @ 100°F)

Right gusset	*Left gusset*	*PE to kraft seamline area*	*Face area unblemished*	*Entire bag*
19.84	28.52	19.84	17.67	60.45
20.30	31.62	19.84	17.36	59.68
20.00	59.21	20.93	18.60	53.32
35.50	18.14	...	17.21	100.60
38.75	23.87	19.22	18.29	44.80
14.11	16.28	...	12.40	70.06
13.33	14.73	...	12.25	19.07
14.83	15.19	13.48	12.25	19.07

In the manufacturing operation in order to form the multiwall tube, the barrier sheet is unwound and fed through a web and then drawn over carrier rollers to the cross-paste section, where adhesive is applied to spot paste and tie the plies together at the bag's opened end. The plies are immediately brought together with staggered edges for the longitudinal seam paste application. From this point the sheets travel downward to a "heel" where the paper changes direction at an angle of approximately 45°. The heel guides the paper over the former and initiates the tubing of the sheets. Simultaneously, projecting rods acting as guides lift the back folds upward, guiding the sheets over the former blades. Here the gussets are formed as the sheets are forcefully folded in and around the former blades, of which two for each gusset are attached to the heel and situated one above the other, extending the entire distance of the tubing section (from 6 to 8 ft). The middle gusset crease is formed by a blade attached to the tuber's frame which protrudes inward immediately between the two blades attached to the heel. The paper drawn over the blades forms the gusset of the bag. The paper plies are staggered so that the back folds and laps each succeeding ply over itself by approximately 1 in., thus forming the side wall seams. The folded continuous tube is drawn through the tube by spring-loaded draw rollers.

The pulling of the paper around the heel and over the former blades does more damage to the barrier ply than any other phase of the converting process. The sheet is pulled around the heel, and the portions which become the gusset and back areas are simultaneously elevated where a crumpling and cracking occurs in the area of the face gusset crease (Fig. 1). These breaks range from no visible cracks, in some cases, to a 1/2 in. break in the cross direction of the sheet. Pinhole and water vapor transmission tests in these areas show a substantial WVT increase.

In order to obtain relative figures demonstrating the effect of forming gusset creases in a barrier, samples were selected from a run in which the overall construction, machine speed, applied lubricant, and web tension were kept constant as far as the machine allowed. Water vapor transmission and pinhole tests made in the gusset and adjacent face areas indicate that the moisture vapor transmission rates are significantly increased due to the converting operation.

Table I illustrates the water vapor transmission rates across each gusset and the adjacent face areas, plus the water vapor transmission rate across the seamline of PE to kraft bonds. It is readily seen that the extent of the cracks and creases inflicted by the tubing process results in an increased water vapor transmission rate of from practically no effect to as much as 200%. The "pinhole" count in the gusset areas (they are actually not pinholes but cracks caused by forming section previously described) shows marked increase over the face area of the same sample. The increased water vapor transmission rates obtained by the accelerated storage method as against the GFWVT method is partly attributed to the greater amount of water vapor transmitted through the damaged areas.

By varying the machine speed on different paper samples of different coating weights but otherwise identical bag constructions, it was found that there was no systematic increase or decrease of pinhole count or water vapor transmission rate in the gusset creases. Thus it was tentatively concluded that the machine speed is not a significant factor in causing the cracking of the barriers in the gusset creases. The cause is primarily attributed to the tension applied on the roll in the web, plus the type and amount of lubricant sprayed on the sheet prior to tube formation.

BAG CLOSURES

There are three principal methods of sealing bags for moistureproofness:

1. A polyethylene wax adhesive and coating combination extruded on kraft tape, which in turn covers stitching.
2. A placement of a polyethylene seamless tube inside a flat tube open mouth multiwall bag (nongusseted) and then heat sealing the end of the polyethylene tube above the sewing line with thermal or dielectric heat.
3. Dipping the sewn ends in hot wax mixture.

GFWVT tests made on the seal portion of a seamless tube across the diameter of the cup in conjunction with the adjacent areas of the tube have shown no significant water vapor transmission difference. On the other hand, special cups prepared for making WVT tests by this gravimetric method through the taped portion of the end of the bag recorded significantly increased moisture rates over the barrier ply. Cups were especially designed for making these measurements. Results of several closures at 73°F and 50% RH are:

Type closures	*g/m²/24 hr*
1. Sewn through (no barrier)	127.31
2. Wax under tape	100.78
3. Extruded polyethylene wax mixture	37.37
4. Asphalt tape-over-stitch	34.16
5. Wax dipped	16.84

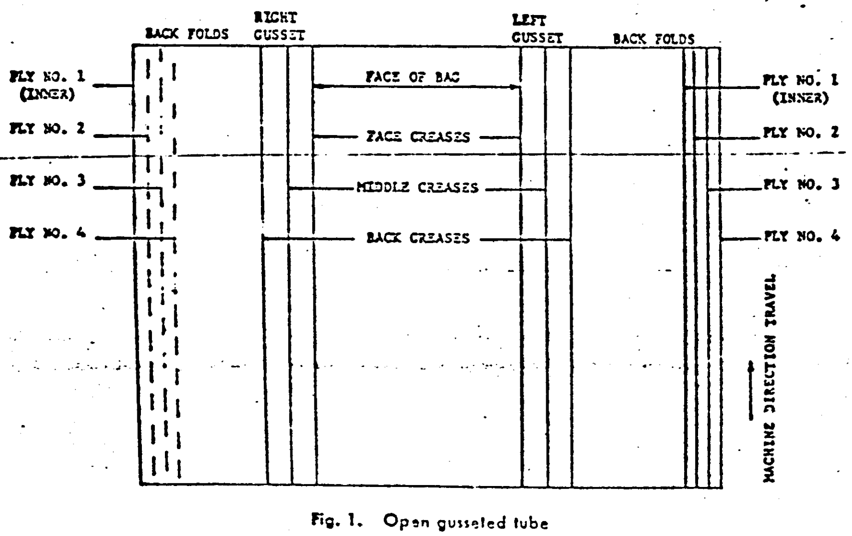

Fig. 1. Open gusseted tube

Table II. Pinhole Count for 31 sq in. of Area in Each Gusset Crease of the Coated Sheet

Sample number	Right gusset: Face crease	Right gusset: Middle crease	Right gusset: Back crease	Left gusset: Face crease	Left gusset: Middle crease	Left gusset: Back crease	Face area, 360 in.²
1	20	28	18	70	[a]	22	10
2	4	38	21	42	[a]	16	9
3	19	42	12	52	56	41	18
4	25	50	12	64	75	12	6
5	19	37	15	[a]	44	12	7
6	19	34	19	[a]	65	21	14
7	45	[a]	18	50	28	7	20
8	48	[a]	14	40	[b]	4	11
9	3	48	18	25	22	1	0
10	7	33	16	30	38	3	0
11	67	[a]	17	104	[a]	6	6
12	75	[a]	12	90	[a]	5	3
13	6	51	17	42	43	3	1
14	11	37	12	30	50	3	0
15	5	40	10	35	37	2	4
16	8	43	17	30	20	3	4
17	4	4	8	23	2	0	0
18[c]	35	62	11	24	93	24	5
19	38	18	120	...	...	...	50

[a] Almost a continuous break.
[b] Exceedingly speckled with very small breaks.
[c] Positioned as the number 3-ply in a 6-ply bag.

PINHOLES

Pinholes are commonly referred to as small areas of coating voids. These voids are detected by various procedures, such as TAPPI T 454 m-60, and by the method of detection used in this laboratory. The latter simply involves smearing penetrating oil over a predetermined area of the coating at room conditions and observing for penetration within three to five minutes. Penetration is detected by discoloration of the kraft substrate

To a large extent, pinholes in the gusset creases are actually not pinholes, as described by the above definition, but cracks and rubbed areas where the coating has actually rubbed off. The face and back creases of the gusset are areas where the rubbing occurs. The middle crease is the area where the cracking of the coating is most noticeable, although the former blade is not in contact with the coating at this point when the coating is positioned as the inside ply with the coated side facing inward. The reverse is true when the coated ply is the outside ply with the coating facing outward. Face creases (Fig. 1) often exhibit the most pronounced cracking and creasing. In this area, there is a more rapid penetration of the oil, and a greater area is stained beneath the coating. Practically all water vapor penetration is attributed to the cracking of the barriers (Table II).

PLY POSITIONING

At times in bag construction designing, it is possible to increase the moisture resistance effectiveness of the barrier plies by exposing the coated side to the higher humidity.

Numerous water vapor transmission tests of polyethylene-coated papers have shown that, in particular, the lower coating weights have a pronounced two-sidedness; that is, when the coated side is in contact with the high-humidity conditions, the water vapor transmission rate is lower than when the kraft substrate is facing the higher humidity. Similar findings are explained by Bhargava, Rogers, Stannett, and Szwarc in this manner, "... considering that with a fibrous surface such as kraft ... the cellulose fibers ... penetrate the coating completely, whereas with thicker coatings, most of the fibers only partially penetrate the plastic film. The fibers swell in the humid atmosphere and act as wicks and carry water vapor either completely or partially through the film. Thus when the paper side is exposed to the higher humidity, a greater water vapor permeation rate is found than when the 'wicks' are on the dry side. Those wicks which penetrate the film completely are equally effective regardless of which side is exposed to the higher humidity, and lead to an overall higher rate of permeation for the barrier" (*1*). These results correlate with the findings of Violette in the study of pinholes of polyethylene-coated papers. It was found that there was a tendency for the number of pinholes to increase as the surface of the substrate became rougher and as the moisture content of the substrate diminished at the time of coating (*2*). The exact relationship between the number of pinholes and pinhole size and water vapor transmission rates has not been determined.

DOUBLE BARRIERS

Some products require more moisture protection than is supplied by a single coated sheet, or at times it is desirable to position moisture barriers within the walls of a sack for more advantageous protection, such as inside-coated plies facing inward, and outside-coated plies

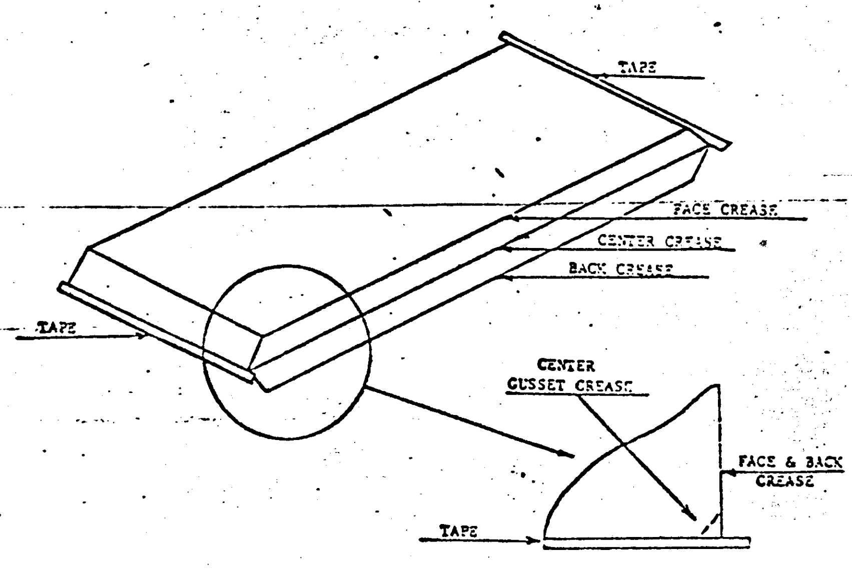

Fig. 2. Filled sewn gusseted bag

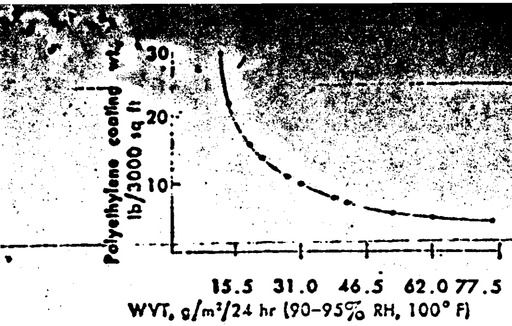

Fig. 3. Water vapor transmission of low-density polyethylene

facing outward. This provides the kraft plies with protection from product attack and the entire unit protection from the outside elements. The outer coating is not as effective as the inner, since it is subjected to additional abrasion, scars, tears, and crumpling encountered in filling and in shipment. Ninnemann and Simerl (3) reported that the number of layers of polyethylene film doubled the protection value. This is found to be true for polyethylene film and coatings in the lower coating weights and film thickness (Fig. 3).

Recent outside storage tests (during the winter months) revealed the behavior of polyethylene-coated plies facing outward exposed to the elements. These tests showed that a ten-pound coating of polyethylene on the outside ply and 2.0 mil polyethylene free film ply as the inside ply of bags filled with 0–20–20-analysis fertilizer would adequately protect the kraft side walls for approximately 30 days. At the end of this period, the water penetrating through the coating during rainy periods and high humidity conditions (approx. 3 in. of rainfall) became trapped beneath the coating and could not dissipate during dry weather, resulting in a weakened bag because of the wetted kraft paper (6). Since the wetted areas were localized, it was concluded that pinholes were a contributing factor.

COATING WEIGHT SELECTION

Selection of a coating weight to give adequate protection to the product depends mainly on the hygroscopicity of the material and the ambient atmospheric conditions the filled bag will be subjected to prior to emptying. Accelerated storage tests often reveal which barrier is most capable of economically packaging and protecting the product. The surrounding conditions are most important, as demonstrated by the water vapor transmission rate through a sheet at 100°F and 90% RH (using calcium chloride as the desiccant and reported in g/m²/24 hr) and the moisture rate at 0°F and 90% RH. For a given sample, these results as calculated by Brickman (4) may have a water vapor transmission rate as high as "10 g/100 in.²/24 hr at 100°F and 0.21 g/100 in.²/24 hr at 0°F." However, in bag designing, the most adverse conditions the bag might be subjected to should be the basis for determining the type and weight of the barrier in the sack construction—that is, if complete product protection is desired.

ACCELERATED STORAGE METHOD OF WVT MEASUREMENT

This method is used for determining water vapor transmission rates through multiwall bags, thus providing a more realistic means for economically designing side wall construction and bag types.

DESCRIPTION OF APPARATUS

Variable Humidity Room

This room is designed for testing of paper and paper products under controlled atmospheric conditions ranging from maximum and minimum limitations of 130°F and 95% RH to −5°F and 40% RH.

From inside to outside the walls and ceiling are constructed of the materials in order as outlined below:

1. Three coats of asphalt base aluminum paint.
2. Common brick.
3. Aluminum sheet vapor barrier —0.003 in. thick.
4. Layer of 3-in. AE-F Fiberglas insulation.
5. Asphalt coating.
6. Layer of 3-in. AE-F Fiberglas insulation.
7. Aluminum sheet vapor barrier —0.003 in. thick.
8. Plywood paneling.

The floor is constructed as follows:

1. Three-inch concrete slab.
2. Polyethylene barrier —0.003 in.
3. Layer of AE-F Fiberglas insulation.
4. Asphalt coating.
5. Layer of 3-in. AE-F Fiberglas insulation.
6. Aluminum vapor barrier.
7. Six-inch concrete slab reinforced.

The door is a Jamison VAP-R-TYP cold storage, having additional rubber gaskets installed on the door frame to minimize moisture vapor leakage.

The housing of the chilling coils, steam injection points, reheat coils, and air ducts is located outside the room and encased in ¹/₄ in. galvanized sheet metal and then a 2 in. layer of cork using an asphalt base sealer.

Relative humidity is controlled by a Honeywell pneumatically operated control unit, utilizing a Foxboro Dewcel element sensing device for moisture measurements. The dry bulb temperature is controlled by a pneumatically operated Honeywell control and recording instrument.

Air circulation is a closed system which is heated, reheated, cooled, dried, or moistened as the sensing controls demand. Moisture is added in the form of steam. The air is dried by condensation (being passed over refrigeration coils). Temperature is raised by both reheating coils and adding steam, depending on the indexed conditions. The room provides an excellent means for storage of filled bags under varying conditions.

Scales

When weighing bags of 10 to 100 lb capacity, scales recording in pounds and ounces are used.

Sampling for Accelerated Storage Tests

Machine-made samples representative of accepted quality levels are selected.

Testing for Moisture Penetration

Samples to be tested are preconditioned for 72 hr at 73°F and 50% RH. A minimum of five samples from each item tested are filled with 10 lb of technical grade calcium chloride, and closed. The standard top closure for the laboratory tests is as outlined below, since the facilities for making a regular hot melt adhesive tape-over-stitch closure are not available:

1. Cushion-stitch closure—25 PE 50 Tape—cotton thread, regular twisted kraft reinforcing cord.
2. 20 PE 50 NK tape heat sealed over the sewn end.

Specimen size encompasses 527 sq in. After filling and closing, the samples are identified and weighed. If desired, three specimens are vibrated on a Gaynes vibration tester at 350 rpm for 3 min on each side and identified as a vibrated sample. The samples are then placed in the variable humidity room on specially designed racks mounted on casters which permits racks to be rolled from the room for conditioning before weighing. These racks are designed to permit free access of the circulating air to all parts of the bag. After 18 hr exposure to prescribed conditions, the specimens are removed and conditioned at 73°F and 50% RH for 6 hr prior to weighing. Samples are weighed and replaced on the racks on the opposite side from the one stored on the previous day.

The procedure is similar to the General Foods method of water vapor transmission measurement in which the test cups are placed in the cabinet for 24 hr, removed, placed in the desiccator for 4 hr, weighed, placed in the cabinet for 68 hr, removed, placed in the desiccator for 4 hr, and weighed. The weight gained, multiplied by an appropriate factor, converts to units of g/m²/24 hr.

For control purposes, two unfilled bags are closed as described, tested, and weighed along with the filled bags. Weight data from these bags are used in adjusting the moisture absorption of the desiccant from that of the paper and closing materials.

The process of removing from the variable humidity room, placing in the constant humidity room and weighing is repeated each day for a maximum of 15 days. The procedure requires preconditioning of the specimen for 72 hr prior to the initial weighing. Then the samples are weighed each day until a steady state of water vapor transfer is attained and reported in g/m²/24 hr.

RESULTS

The water vapor transmission rate for a completed multiwall bag is not only a measure of the water vapor permeability of the side wall barriers, but also a derivative of other characteristics of the package as a complete unit. The WVT rate is significantly affected by variables introduced in manufacturing, such as completeness of closure, effect of creasing, crumpling, and frictional drag on the barrier during tubing. Similar findings were reported by Pierce and Helms (*6*) on various types of frozen food containers tested at 0°F. For comparative purposes, it is advantageous to report the rate gain of accelerated storage test specimen in the units of the General Foods water vapor transmission test. It has been previously determined that kraft plies do not offer resistance to WVT in a multiwall bag (*1*, *7*). The following table lists the WVT of the bag and the barrier ply.

g/m²/24 hr (90–95% RH @ 100°F) Cup test	Bag test
18.60	53.32
17.21	44.80
12.25	19.07

As expected, several groups of tests having same barrier qualities showed considerable variation in the rate gained. However, all were consistently higher than the corresponding General Food's cup tests. From these rates, an estimate can be made of the extent that the closures and coating deformations contribute to the water vapor transmission rate of the entire package. Reproducibility due to variation of products and samples is not expected using the accelerated storage test method. However, field performance and indicative values derived from this method have justified its use for multiwall bag designing by placing a particular product within a particular moisture protection range for testing.

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