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TECHNICAL REPORT 3976

PERFORMANCE OF CURRENT AND NEW WATERVAPOR BARRIER MATERIALS WHEN USED IN BAGS FOR PACKING AMMONIUM NITRATE

SYLVESTRO RUFFINI

MARCH 1970

PICATINNY ARSENAL
DOVER, NEW JERSEY

Technical Report 3976

PERFORMANCE OF CURRENT AND NEW WATERVAPOR BARRIER MATERIALS WHEN USED IN BAGS FOR PACKING AMMONIUM NITRATE

by

Sylvestro Ruffini

March 1970

Munitions Packaging Laboratory
Feltman Research Laboratories
Picatinny Arsenal
Dover, New Jersey

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SUMMARY

During the first stage of this investigation (Phase 1), the performance of the multiwall Kraft paper/polyethylene bag currently used to pack and ship ammonium nitrate (NH_4NO_3) was studied. It was found that the 1½ mil polyethylene barrier will provide watervapor protection for only 2-5 days without exceeding the allowable moisture pickup for NH_4NO_3 (.15% by weight, i.e., till solidification, or "caking" begins). This period of protection is not considered adequate, since it may reasonably be expected that the NH_4NO_3 will be in storage at the loading plant for 30-60 days.

Since solidification of the NH_4NO_3 (an ingredient in the manufacture of explosives) is objectionable during processing at loading plants, work was initiated on a second phase (Phase 2) to improve bag performance. All barrier materials and bag constructions tried in Phase 2 were judged to be better than the bag currently used. The Tyvek and all polyethylene bags, two of the materials selected, improved protection of the contents from watervapor to 40 and 22 days, respectively.

It should be understood that the performance determined in this report for each of the materials was based on laboratory tests conducted on the watervapor barrier material only, and that a final evaluation of any bag material should be based on actual user tests of the complete bag.

INTRODUCTION

The Special Munitions Container Development Section (SMCDS), MPL, FRL, received a request from Bomb and Bomb Fuze Laboratory (BBFL), AED, to investigate the solidification (caking) of the ammonium nitrate (NH_4NO_3), which is occurring in the current multiwall packing bag at Army ammunition loading plants.

In preliminary discussions with BBFL personnel, it was established that the caking may be a result of any of the following 3 factors, alone or in combination:

1. Crystalline phase change of the NH_4NO_3 due to temperature changes.

2. Pressure induced through stacking of bags at loading plants.

3. Watervapor permeation through the bag used to pack the NH_4NO_3.

For the purpose of this investigation, it was assumed that NH_4NO_3 starts to cake when the moisture pickup of .15%, permitted by Specification PAPD-3087A, is exceeded. It was also established that the bag should provide a 30-60 day storage capability without caking of NH_4NO_3.

This report will be confined to investigating factor 3 as if it were the sole contributor to the solidification of NH_4NO_3. The report is divided into 2 phases: Phase 1 deals with the investigation of the effectiveness of the current bag material as a watervapor barrier, and Phase 2 contains an evaluation of other types of watervapor barriers and/or bag constructions which were investigated in an effort to improve the effectiveness of the bag.

DISCUSSION, PHASE 1

The first phase of this investigation was conducted to determine the watervapor transmission rate (WVTR) of the bag now used for packing NH_4NO_3. The currently used bag consists of an inner ply of 50-lb Kraft paper, a second ply of 1 1/2 mil polyethylene (PE), third and fourth plies of 50-lb Kraft paper, and an outer ply of 50-lb W. S. Kraft paper. The companies currently supplying this bag to NH_4NO_3 producers are listed in Table 1.

TABLE 1

Companies supplying bags to contractor packaging the NH_4NO_3

Bag Co.	NH_4NO_3 Producer
Olin Bag Co	U. S. Powder Co
Bemis Bag Co	DuPont Co
Crown Zellerback Corp	Hercules Co
Arkel Safety Bag Co (Chase)	National Powder Co

Since SMCDS does not have facilities at Picatinny to perform WVTR tests, sample specimens of new bags from each company were forwarded to AMC Packaging and Storage Center (AMCPSC) at Tobyhanna Army Depot for evaluation. The test methods used, thickness measurements, and WVTR results obtained in tests of these specimens are given in AMCPSC Test Report WAL 71-69 dated June 1969 (Appendix A).

A summation of pertinent data is presented in Table 2.

TABLE 2

Summation of pertinent data from AMCPSC Test Report WAL 71-69

	AVG WVTR[a] (g/100 sq in/24 hrs)	AVG THICKNESS[c] (MIL)
Olin (large bag)	0.4	2
Olin (small bag)	0.5	1.7
Bemis[b]	0.7	1.5
CZ Corp	0.8	1.5
Chase	0.9	1.0

[a] WVTR based on test temperature of 100°F and relative humidity (RH) of 90%.

[b] This was a used bag. New specimen did not arrive on time.

[c] Thickness applies to PE film ply only. PE film is the only barrier in bag construction that provides water-vapor protection.

As is indicated above, the average thickness of the PE film varies from 1 to 2 mil and the average WVTR varies from .4 to .9. To evaluate bag performance, it is necessary to establish the time required for the NH_4NO_3, when packed in the current bag, to reach and exceed the maximum moisture pickup requirement of .15% specified in the NH_4NO_3 purchase description, PA-PD-3087A.

An analytical evaluation was carried out involving the following assumptions:

1. The moisture content of the NH_4NO_3 is controlled at a maximum level of .075% during the packing process

2. Caking begins when .15% moisture pickup is exceeded. Subtracting the .075% moisture that may be picked up during packing (see 1 directly above) leaves only .075% moisture that may be picked up by the bag

3. Weight per bag: 50 pounds

4. Bag size (average): 25 1/2 × 17 in.

5. Bag surface area: 865 sq. in.

On the basis of the above assumptions, the following calculations can be performed to determine bag performance:

Grams (g)/50 lb of NH_4NO_3 - X (Conversion factor: 2.205×10^{-3} lb/g)

$$X = \frac{50 \text{ lb}}{2.205 \times 10^{-3} \text{ lb/g}}$$

$$X = 22.8 \times 10^{+3} \text{ g/50 lb of } NH_4NO_3$$

Total moisture pickup (grams) in 50 lb of NH_4NO_3 - Y

Based upon .075% moisture pickup permitted after packing of NH_4NO_3,

$$Y = X\ (.075\%)$$

$$Y = 22.8 \times 10^3 \times .75 \times 10^{-3}$$

$$= 17.1 \text{ g/50 lb of } NH_4NO_3$$

Using the WVTR values of .4 g/100 sq. in./24 hr (Olin) and .9 g/100 sq. in./24 hr (Chase) obtained from Table 2, the following can be determined:

Total moisture pickup (grams) /bag/24 hr - Z

(bag area - 865 sq. in.)

$$\text{Olin Bag} \quad - Z_1 = \frac{.4\text{g}}{100 \text{ sq in./24 hr}} \times 865 \text{ sq in.} = 3.46 \text{ g/24 hr/bag}$$

$$\text{Chase Bag} \quad - Z_2 = \frac{.9\text{g}}{100 \text{ sq in./24 hr}} \times 865 \text{ sq in.} = 7.8 \text{ g/24 hr/bag}$$

Number of hours (H) to exceed max moisture (Y)

$$H_1 = \frac{Y}{Z_1} = \frac{17.1 \text{ g}}{3.46 \text{ g/24 hr}} = 120 \text{ hours or 5 days (best)}$$

$$H_2 = \frac{Y}{Z_2} = \frac{17.1 \text{ g}}{7.8 \text{ g/24 hr}} = 53 \text{ hours or 2.2 days (min)}$$

CONCLUSIONS, PHASE 1

It appears that the best watervapor protection that can be expected from the currently supplied bags is 5 days (minimum 2.2 days), after NH_4NO_3 is packed, before the .15% moisture pickup (start of caking) allowed by specification is exceeded. However, it should be understood that the bag performance data is based on specimen test results obtained at a temperature of 100°F and an RH of 90%. Therefore any variation in temperature-RH conditions, and even allowable moisture pickup, would tend to increase or decrease bag performance (most likely increase). However, the temperature-RH condition of 100°F and 90% can be obtained for a sustained period of time during the summer months, especially if the loading plants are located in a southerly geographic area and if storage areas are not temperature-RH controlled.

After discussions with BBFL personnel, it was decided, because of the possibility that the current Kraft paper/PE bag might perform poorly, that a Phase 2 study should be initiated. This phase of the investigation would involve trying to improve the barrier material and/or construction of the bag to meet the requirement that, during a 30-60 day storage period, moisture pickup should not exceed .15%.

DISCUSSION, PHASE 2

Various barrier materials and bag constructions were considered for use in the second phase of the investigation. The barrier materials and bag constructions selected are listed in Table 3.

TABLE 3

Barrier materials and bag constructions selected for Phase 2

Bag Material and Construction	Bag Supplier
All Tyvek (aluminum particles dispersed in spun polyethylene), meets requirements of Spec MIL-B-131	Chase
All polyethylene film (7-9 mil)	Chase
4 Kraft plies w/1 ply PE (5 mil)	Crown-Zellerback
4 Kraft plies w/1 ply aluminium foil (7 mil) sandwich between layers of PE (1 mil)	Crown-Zellerback

Specimens of the bags listed in Table 3 were forwarded to AMCPSC for evaluation as had previously been done in Phase 1. Test methods used, thickness measurements and WVTR results are given in a letter report from AMCPSC dated 19 Sep 69 (Appendix B). Pertinent test results are listed in Table 4.

TABLE 4

Pertinent data from AMCPSC letter report dated 19 September 1969

Bag Material	Avg WVTR, g/100 sq in./24 hrs)	Avg Thickness, (mil)
Tyvek	.05	10.2
All PE film	.09	8.9
Kraft plies w/PE Liner[a]		
w/seam	0.2	4.4 (PE), 6.9
w/o seam	0.1	(Each Kraft ply)
Kraft plies w/Aluminum Liner[a]		
w/seam	0.5	7.1 (Al), 6.9
w/o seam	0.3	(Each Kraft ply)

[a]Only the liner provides watervapor protection.

Analytical calculation to delineate bag performance, using the assumptions established for Phase 1 produced the information in Table 5. In addition to bag performance data for Phase 2 (Item 2 through 5, Table 5), estimated cost and average bag performance values for the current bag (Item No. 1) are included in Table 5 for purposes of comparison.

CONCLUSIONS, PHASE 2

It can be concluded that every barrier material and bag construction considered in Phase 2 is better than the bag material currently used. Tyvek gives the best results, 40 days before exceeding the moisture pickup requirement; the all polyethylene material gives fair results and certainly should be considered from a cost viewpoint. The results are considered conservative in terms of the assumptions made to determine bag performance and the laboratory controlled techniques; i.e., if the maximum allowable moisture pickup through the bag could be increased to .15% instead of the .075% reported without caking of NH_4NO_3 becoming intolerable for processing, it would double the bag performance for all of the barrier materials. In other words, a Tyvek bag would be capable of providing 80 days of watervapor protection. Therefore, an improvement of 50 to 100% for each barrier material could be realized under actual user conditions.

TABLE 5

Summation of WVTR data (Both Phase 1 and Phase 2)

Bag Identification	Bag Construction[a]	WVTR, g/100 sq in./24 hr	Barrier Thickness Mil	Total Moisture Pickup g/24 hr	Time to Exceed .15% Moisture Pickup[b] Hr/Days	Estimated Price/1000 Bags[c]
1 Current Bag	Inner Ply-50 lb Kraft 2nd Ply-1 1/2 mil PE 3rd & 4th Plies - 50 lb Kraft Outer Ply-50 lb W.S. Kraft	.7 (Avg)	1.5 (Avg)	6.1	67/2.8	$100.00
2 Kraft Plies w/Alum Foil	Inner Ply-50 lb Kraft 2nd Ply)1 mil PE)7 mil Alum Foil)1 mil PE 3rd & 4th Plies - 50 lb Kraft Outer Ply-50 lb W.S. Kraft	.5 (w/seam)	7.1	4.3	96/4	$198.00
3 Kraft Plies w/PE Liner	Inner Ply-50 lb Kraft 2nd Ply-5 mil PE 3rd & 4th Plies - 50 lb Kraft Outer Ply-50 lb W.S. Kraft	.2 (w/seam)	4.4	1.7	240/10	$150.00
4	All Polyethylene (9 mil)	.09	8.9	.78	528/22	$107.00
5	Tyvek 1 Ply-Aluminum Particles in Spun PE	.05	10.2	.43	960/40	$330.00

[a] Total bag surface area, 865 sq in.; weight of contents, 50 pounds.

[b] 17.1 grams/50 lb of NH_4NO_3.

[c] Based on 100,000 lots.

RECOMMENDATIONS

Before any final selection of bag materials is made, further studies should be conducted under actual user conditions. A program using 2 or possibly 3 of the better barrier materials, along with the corresponding bag constructions, should be used in a field test program consisting of shipment from bag company to NH_4NO_3 producer to loading plant, with pertinent data, such as temperature, relative humidity, and moisture pickup, recorded at various time intervals. A similar type of program, with reduced-size bags filled with NH_4NO_3 and using laboratory techniques and facilities, may also be considered as an expedient means of getting the required information.

ACKNOWLEDGMENTS

The author is indebted to Messrs. Richard DeVore of the Munitions Packaging Laboratory and Anthony Alfano of the AMC Packaging and Storage Center, Tobyhanna Army Depot, for their invaluable assistance in this work. Mr. DeVore's contribution included setting up the WVTR test program and coordinating it with AMCPSC. Mr. Alfano produced the test results shown in Appendixes 1 and 2.

APPENDIX A

AMCPSC Test Report WAL 71-69, WVTR Tests of 5-Ply Bags Used to Package Ammonium Nitrate

AMCPSC

Test Report

WAL 71-69

WVTR TESTS OF 5-PLY BAGS USED TO PACKAGE AMMONIUM NITRATE

ANTHONY ALFANO

June 1969

1. Introduction.

This report is the result of a request from Picatinny Arsenal to determine the water vapor transmission rate through bags constructed of 4-ply kraft paper and 1-ply polyethylene. These bags are used to package ammonium nitrate, an ingredient in explosives. It had been observed at Picatinny that the ammonium nitrate was caking in the bags. This caking, which is indicative of moisture pickup, is undesirable because it favors the misfiring of explosives and munitions; and presents a difficulty in dispensing. In their investigation of the caking problem associated with bagged ammonium nitrate, the Picatinny people wanted to know the water vapor transmission rate of the bags.

2. Discussion.

a. Test Method.

(1) Identification of samples.

The samples submitted for tests were separated into groups and coded at the AMCPSC laboratory. The following table shows the code, the number of specimens taken per bag, and the identification of the bags in each group:

Group	No. of bags	No. of Specimens taken	Identification of bags
A	3 (large)	1 per bag	U.S. Powder Company Prch No. 5551 488 5-180 8-5347 Rec'd. 4-18-69
B	3 (small)	1 per bag	U.S. Powder Company Lot No. 19 C-10/68 400-69-C-0565 488 8-4526 4-200

Group	No. of bags	No. of Specimens taken	Identification of bags
C*	1	2	E.I.DuPont De Nemours Co. C2-69 Lot No. 13-16 DSA 400-69-C-3318 Polywall Dura-Grid Bemis Bag Co., Inc., Mobile 1-69 HOD-1012
D	2	1 per bag	Hercules, Inc. DSA 400-69-C-4550 2-85862 17005.5 Crown Zellerbach Corp. Bogalusa, Louisiana PO 081-01855 4-200 Plus PE Crown polyethylene ply
E	2	3	National Powder Co. C-3/69 Lot No. 27 Contr DSA-400-69-C-3317 Stack Aide Arkell Safety Bag Co. A-9 Rec'd 4/18/69

* This was a used bag.

(2) Construction of bags

The bags were constructed of 5-ply material. Four plies consisted of kraft paper and one ply consisted of polyethylene. The bags in group A were constructed with the polyethylene as the first innermost ply. All other bags were constructed with the polyethylene as the second ply after the innermost paper ply.

(3) Procedure

The water vapor transmission rate was determined according to Method 182 of UU-P-31b, Paper; General Specifications and Methods of Testing.

b. Test Results

Group	WVTR g/24 hr/sq meter	WVTR g/24 hr/100 sq in
A	6.9	0.4
	6.9	0.4
	6.9	0.4
B	N.G. (polyethylene not sealed)	
	7.7	0.5
	7.7	0.5
C	11.5	0.7
	10.8	0.7
D	13.1	0.8
	13.1	0.8
E	N.G. - hole in dish	
	N.G. - hole in polyethylene	
	14.6	0.9

3. Other tests

The thickness of the polyethylene barrier was measured. The following results were obtained from the specimens after the WVTR was determined. Included in this tabulation is the average WVTR corresponding with the specimens.

Group	Average thickness (mils)	Average WVTR (g/24 hr/100 sq in)
A	2	0.4
B	1.7 (estimated)	0.5
C	1.5 (estimated)	0.7
D	1.5 (estimated)	0.8
E	1.0	0.9

4. Conclusion

The test results bear out the fact that there is an inverse relationship between the thickness of the polyethylene and the water vapor transmission rate. The thickness of the polyethylene is primarily responsible for the variation in WVTR among the bags tested.

5. Remarks

Although the selection of specimens from each bag was limited (only one to two specimens per bag), it was nevertheless observed that two out of the five bags tested were constructed with a defect in the polyethylene barrier. Such bags offer no protection against moisture. The defective barrier in the type of 5-ply bags submitted for tests may be the main factor for the caking of bagged ammonium nitrate.

APPENDIX B

Ltr 19 Sept 1969, Subject: WVTR of Shipping Bags. From E. H. Borkenhagen to SMUPA-VP-2

AMXTO-TL 19 Sep 1969

SUBJECT: WVTR of Shipping Bags

Commanding Officer
Picatinny Arsenal
ATTN: SMUPA-VP-2
Dover, New Jersey 07801

1. This report confirms the information given by Mr. Alfano of this center to Messrs. Steve Ruffini and Richard DeVore of your facility on 26 August 1969 by telephone.

2. The water vapor transmission rate was determined according to Method 182 of UU-P-31b, Paper; General Specifications and Methods of Testing, after low temperature flexing of the bag materials according to para 4.6.5 of MIL-B-131E(1) Barrier Material, Water-vaporproof, Flexible, Heat Sealable.

3. Thickness measurements were determined according to Method 1003 of Federal Test Method Standard No. 101B after the specimens were conditioned to equilibrium in the environment prescribed in Federal Standard No. 1.

4. The following test results were obtained:

Bag Material		WVTR in g/24 hrs/100 sq in
MIL-B-131E (Tyvek-backed) (10.2 mils)		0.05
Polyethylene (8.9 mils)		0.09
Kraft paper plies with polyethylene (4.4 mils) liner	w/seam	0.2
	w/o/seam	0.1
Kraft paper plies with aluminum foil liner (7.1 mils aluminum foil and kraft paper ply)	w/seam	0.5
	w/o/seam	0.3

AMXTO-TL
SUBJECT: WVTR of Shipping Bags

5. The kraft paper in each of the two bags submitted measured approximately 6.9 mils per ply.

FOR THE COMMANDER:

E. H. BORKENHAGEN
Chief, Engineering and
Laboratory Division
AMC Packaging and Storage Center

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Picatinny Arsenal, Dover, New Jersey 07801	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
PERFORMANCE OF CURRENT AND NEW WATERVAPOR BARRIER MATERIALS WHEN USED IN BAGS FOR PACKING AMMONIUM NITRATE

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

Sylvestro Ruffini

6. REPORT DATE March 1970	7a. TOTAL NO. OF PAGES 28	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report 3976 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	

10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

During the first stage of this investigation (Phase 1), the performance of the multiwall Kraft paper/polyethylene bag currently used to pack and ship ammonium nitrate (NH_4NO_3) was studied. It was found that the 1½ mil polyethylene barrier will provide watervapor protection for only 2-5 days without exceeding the allowable moisture pickup for NH_4NO_3 (.15% by weight, i.e., till solidification, or "caking" begins). This period of protection is not considered adequate, since it may reasonably be expected that the NH_4NO_3 will be in storage at the loading plant for 30-60 days.

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It should be understood that the performance determined in this report for each of the materials was based on laboratory tests conducted on the watervapor barrier material only, and that a final evaluation of any bag material should be based on actual user tests of the complete bag.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Watervapor barrier material						
Ammonium nitrate						
Bag material						
Multiwall Kraft paper						
Polyethylene						
Tyvek						