AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON D C 20523

# BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
0194

1 SUBJECT CLASSIFICATION

A PRIMARY
Agriculture AF25-0000-0000

B SECONDARY
Soil fertility,fertilizers,and plant nutrition

2. TITLE AND SUBTITLE
Improvement in efficiency of handling bagged fertilizer

3 AUTHOR(S)
Silverberg,Julius; Harrison,C.P.

| 4 DOCUMENT DATE | 5 NUMBER OF PAGES | 6 ARC NUMBER |
|---|---|---|
| 1971 | 11p. | ARC |

7 REFERENCE ORGANIZATION NAME AND ADDRESS
TVA

8 SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*
(In NFDC bul.Y-31)

9 ABSTRACT

10 CONTROL NUMBER
PN-RAA - 143

11 PRICE OF DOCUMENT

12 DESCRIPTORS
Bagging
Materials handling
Polyethylene

13 PROJECT NUMBER

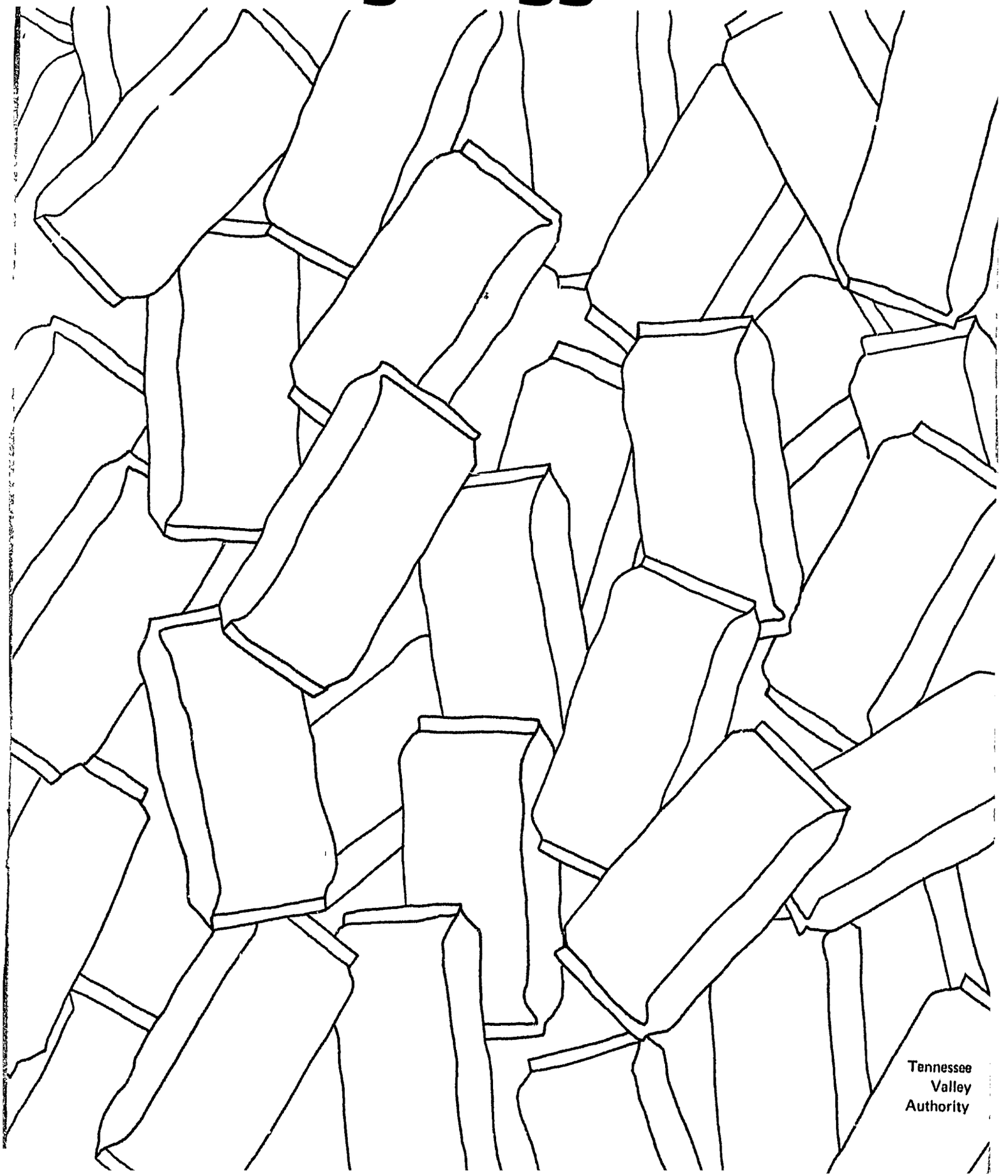
14 CONTRACT NUMBER
PASA TA(QA)6-69 GTS

15 TYPE OF DOCUMENT

AID 590 1 (4 74)

4

# Improvement In Efficiency Of Handling Bagged Fertilizer



Tennessee
Valley
Authority

Prepared for the

TA(QA)6 69

AGENCY FOR INTERNATIONAL DEVELOPMENT

by

Julius Silverberg and Cecil P Harrison

## TABLE OF CONTENTS


| | |
|---|---|
| Summary | 4 |
| Introduction | 4 |
| Test Procedures | 4 |
| Hook Tests | 4 |
| Drop Test | 5 |
| Moisture Penetration | 6 |
| Deterioration of Bag Materials | 6 |
| Results with Jute/PE Bags | 7 |
| Hook and Drop Tests | 7 |
| Moisture Penetration | 7 |
| Deterioration of Bag Materials | 7 |
| Inspection of Damaged Bags | 8 |
| Results with PP/PE Bags | 10 |
| Estimated Costs of Bags | 10 |
| Recommendations | 10 |

# IMPROVEMENT IN EFFICIENCY OF HANDLING BAGGED FERTILIZER


## SUMMARY

A study was made for the purpose of improving the efficiency of handling bagged fertilizers shipped to the developing countries (DCs) Emphasis was placed on the handling of hygroscopic fertilizers in 50 kg, 10 oz jute bags with loose polyethylene (PE) liners Limited tests of 50 kg woven polypropylene (PP) bags with PE liners lso were made

Best results were obtained with a novel TVA design comprising two concentric polyethylene liners The improvement is ascribed to the fact that, when the bag of fertilizer is moved after being punctured with a hook, the liners are no longer aligned but, in effect, are closed

It was recommended that (1) test shipments be made of urea in 10 oz jute bags with double PE liners, (2) consideration be given to test shipments in woven PP with single and double liners because PP is more resistant to tearing and does not lose strength when exposed to fertilizer salts or salt water, and (3) a study be made of the feasibility of using smaller packages, which might not be handled with the aid of hooks The costs of the 10 oz jute bags with double liners are estimated to be from 3 5 to 8 0¢ more than the cost of the currently approved jute bag with single liner Woven PP bags cost a few cents less than the jute bags

Other changes that might help reduce fertilizer losses are (1) establishment of penalties and incentives, according to losses incurred, for crews handling fertilizers, (2) development of bags having specific hooking areas together with incentives for their use, and (3) the ultimate of eliminating, completely, the use of hooks


## INTRODUCTION

This report covers a study directed toward improving the efficiency of handling bagged fertilizers shipped to the DCs Emphasis was placed on the handling of hygroscopic fertilizers in 50 kg, 10 oz jute bags with loose PE liners, because of the reported extensive damage to this AID approved bag[1] when handled with the aid of hooks Limited tests of 50 kg woven PP bags with PE liners also were made

Discussions were held with bag manufacturers to obtain information on bag testing procedures and their recommendations regarding bags for shipping of various types of fertilizers, after which test procedures were designed for use in evaluating the resistance of bags to tearing when handled with the aid of hand hooks and their resistance to bursting when dropped Tests also were made of the resistance of closures to passage of moisture and of the resistance of bag materials to deterioration when in contact with wet fertilizer products The results of these tests are discussed, and recommendations are made for test shipments with bags having two liners, one within the other, rather than the presently used single liner This novel TVA design for fertilizer bags resulted in significant reduction of fertilizer loss from bags handled with the aid of hooks Other points for consideration also are presented

## TEST PROCEDURES

### Hook Tests

The hook test was designed to simulate reported handling of 50 kg jute/PE free liner bags at ports in DCs The test may be more or less severe than actual practice since handling in foreign ports was not observed However, the test permits comparison of various bag types In the single visit made to a U S port where bags were filled and loaded on ships for overseas delivery, handling was by pallet and manual labor without the aid of hooks

Because it has been stated that "bags are hooked as many as 12 16 times just in port operations, alone," the test consisted of 12 hookings, 6 on face and 6 on back, the bag being pulled with the hook about 2 feet on the surface of a table each time The force required to pull the bag was equivalent to about 60 pounds A sketch of the hook is shown in figure 1 Figure 2A shows the areas in which the bags were hooked and the direction of pull force

After the hooking operation, the bag was dropped a total of 12 times, alternately on face and back from a height of 1 foot onto a wire grate Afterwards, it was inspected for liner and outer bag tears Measurements were made of the amount of fertilizer that had sifted through the outer bag and amount of loose fertilizer between the liner and outer bag The amount of loose fertilizer was determined by cutting the outer bag away from the liner (inner bag), turning the liner 180 degrees (bottom over top) as shown in figure 2B and measuring the fertilizer that had escaped from it Bag performance was reported as (1) the amount of fertilizer that spilled during hooking and tumbling and (2) the amount that spilled after the outer

[1]Specifications SBM 68 16A, February 11, 1969 Agency for International Development, Washington, D C

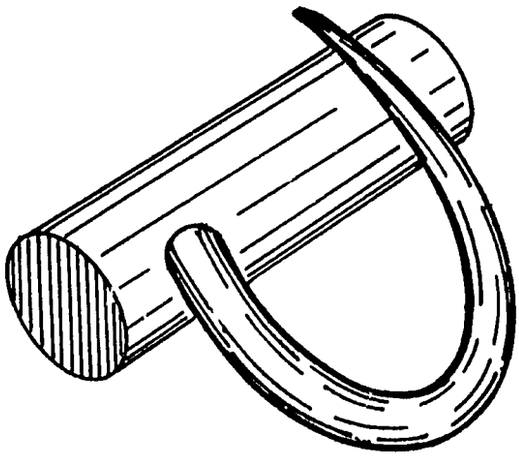


Figure 1 Typical hook used by some DC dock workers

bag was removed and the liner and contents were turned 180 degrees

### Drop Test

The drop test was made from a height of 8½ feet This height was chosen because it was the limit of our electrically powered hoist and sufficiently high to usually cause the standard, single liner, 10 oz jute bag to burst with one drop on one of its sides The procedure consisted of positioning the bag longwise and level in a sling held by a pneumatic clamp so that the sewn edge was up The hoist then was raised and, after further leveling, the sling was released, the sling and bag dropped to a concrete slab in such a manner that impact of the bag was along the nonsewn side Figure 3 shows a bag in position before being

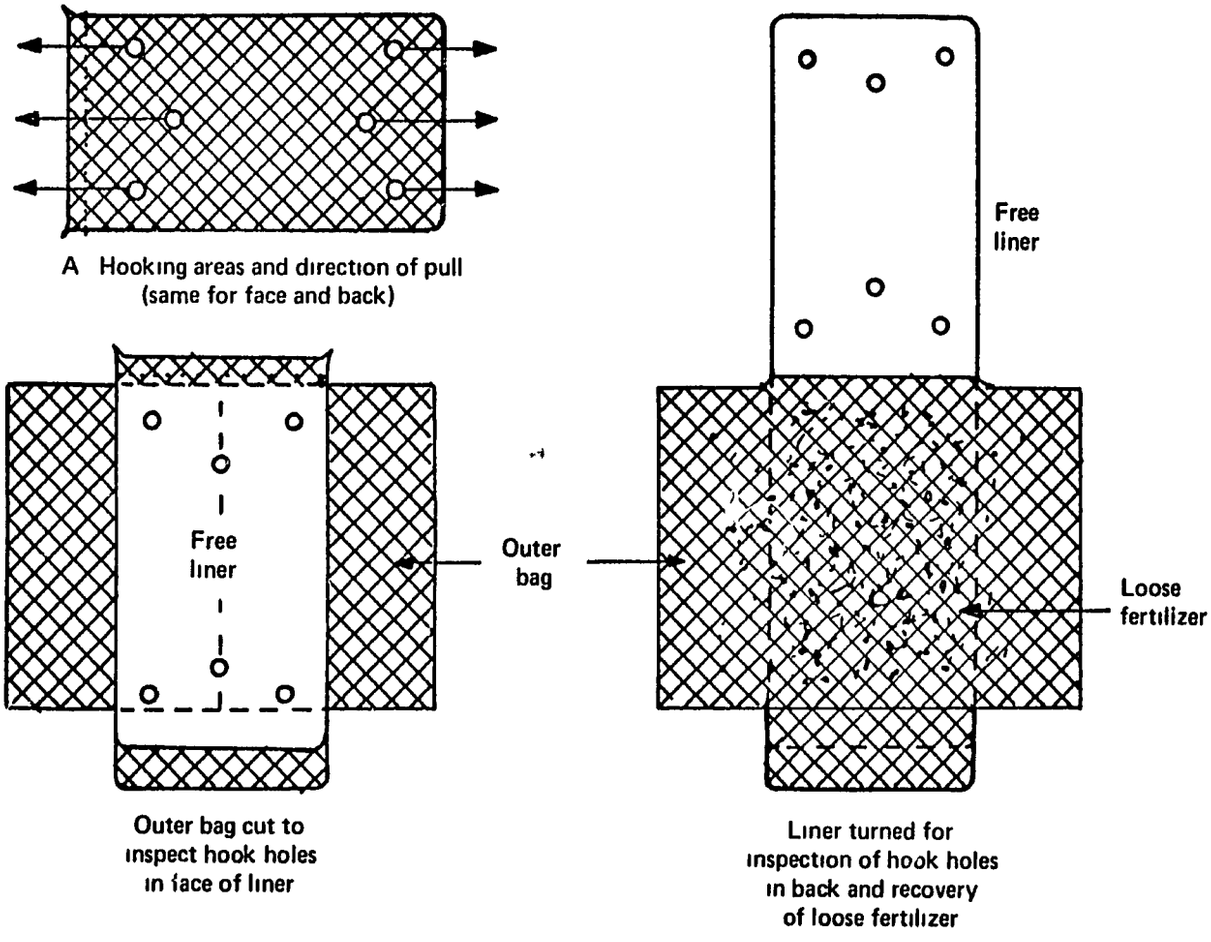



Figure 2 Diagram of hook test for textile-plastic film fertilizer bags

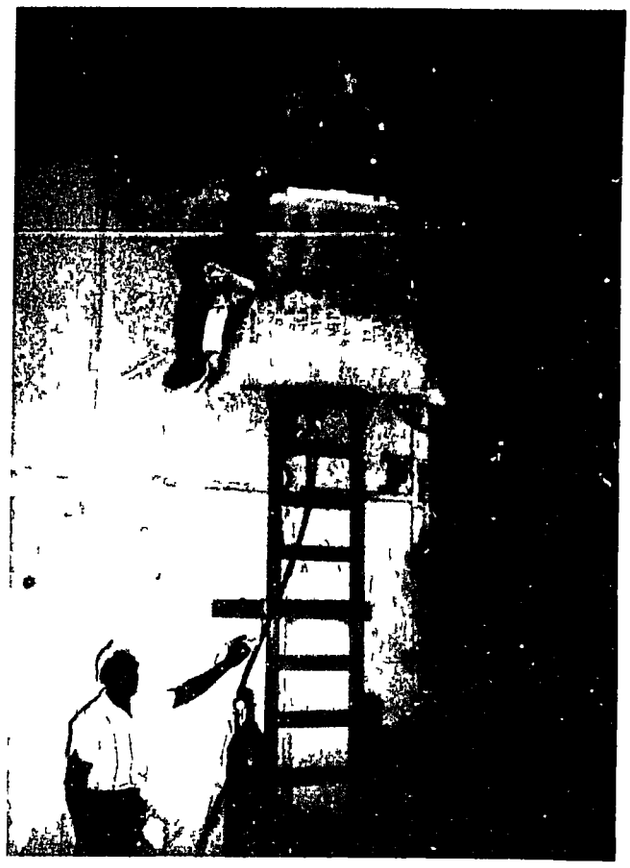


Figure 3 Apparatus used for drop tests

dropped Bag failure was considered to be the number of drops required to result in spillage from the outer bag

### Moisture Penetration

Closures of the free liners in bags for shipment of urea and of other hygroscopic materials were specified (AID) to be hermetically sealed by (1) heat sealing (HS), (2) use of an acid resistant metal clip (tipper tie, TT), or (3) use of a plastic covered wire (bar loop, BL) The outer bag was always closed by sewing However during the course of this study, test shipments were made of bags in which the liners were sewn closed simultaneously with the outer bag (ST) Also, information was obtained on a folded closure Therefore, tests were made to evaluate the efficiency of the various closures for preventing passage of moisture into the fertilizer

The test consisted in exposure of bags of fertilizer to air at 95% relative humidity and 95°F (35°C) After exposure, for about 90 days, the depth of moisture penetration was noted

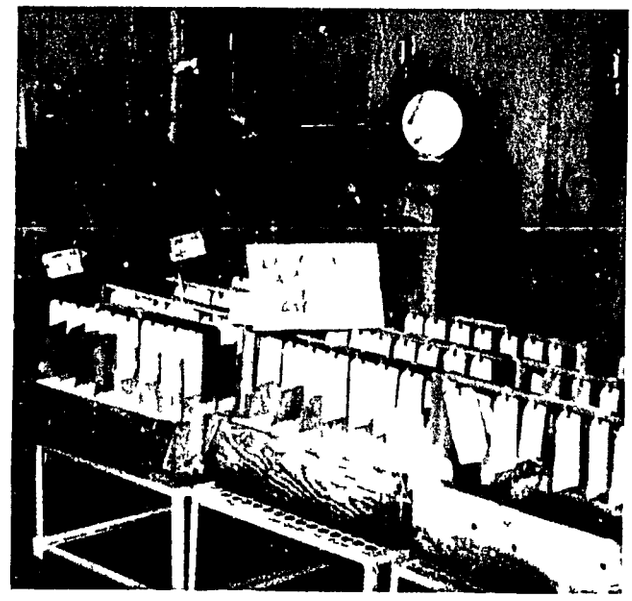


Figure 4 Exposure of sample bag materials to fertilizers

The folded closure, which involved cross folding the top of the PE liner over the fertilizer before sewing the jute, was of interest because it should have the advantage over an untaped sewn closure of preventing inflow of moisture and the advantage over tying of not trapping air and causing a ballooning effect, which is said to give difficulty with stacking of bags Also, compared to tying, closure of the liner by folding should result in a considerable increase in bagging line throughput and some decrease in cost Only limited tests were made of closing by heat sealing because our equipment was not designed for sealing 50 kg bags and because we felt that heat seal closures should give results similar to those obtained with the fold closure

### Deterioration of Bag Materials

Varma and Singh[2] (1) reported that jute deteriorates when in wet contact with most fertilizers, including urea, superphosphate, ammonium nitrate, and diammonium phosphate In the current study, limited tests were made of the resistance of jute and PP to various fertilizers For these tests, fabric specimens, 4 by 9 inches, were cut from new bags and then exposed to various fertilizers by suspending them in a box so that half the specimen was buried in fertilizer and the other half was above the fertilizer (see figure 4) The atmosphere in exposure area was maintained at 95° and 95% relative humidity Exposure time was 5 months

[2]Varma, S and V P Singh *Technology* 5, No 3, 235 36 (July September 1968)

Loss in strength of the materials was determined by a commercial laboratory after washing retained salts from the materials The standard tensile strength test, ASTM D1682, "Breaking Load and Elongation of Textile Fabrics," Method G, Grab Tests, was used

## RESULTS WITH JUTE/PE BAGS

### Hook and Drop Tests

Comparisons were made of jute weight (14 vs 10 oz), PE liner thickness (6, 4, and 2 mils, 0 15, 0 10, and 0 05 mm), type of liner closure [heat seal (HS), tied (TT or BL), folded (CF), and sewn with jute (ST)], single free liners according to AID specifications, and double liners, with and without the outer of the two liners glued to the jute

Hooking the jute bags by the procedure described earlier did not result in appreciable tearing of the cloth However, hooking did result in significant tearing of the PE liners (2 3 inches), which resulted from pulling the hook until the slack in the outer bag was taken up As a result, there usually was little sifting of fertilizer through the outer bag unless moving the bag left the hole in the liner directly in line with the hole in the jute Therefore, as stated earlier, evaluations were based chiefly on the tearing of the liners and the amount of fertilizer that spilled from the liner when the outer bag was removed

The data of table 1 show that best results in the hook tests were obtained with the double liner design and when the outer of the double liner was glued to the jute This design favored the slippage of one liner as related to the other with the result that the hook holes in the inner liner tended to become sealed Closing the inner liner by tying or folding gave the same results and 4 mil + 4 mil, 2 mil + 4 mil, and 2 mil + 2 mil liners were about equal (1 5 oz lost in hook test, Designs J 2A, J 2B, and J 2C)

Very good results (only 6 13 oz loss) also were obtained with double 4 mil free liners (not glued to jute) regardless of type of closure the inner liner closed by folding (J 2D) or by tying (J 2E) or both liners closed by folding simultaneously (J 2F) Good results also were obtained when both liners were sewn closed with the jute (J 2G) However, as pointed out later, fertilizer in bags in which the PE closures were made by sewing became wet when exposed to humid conditions because moisture entered through the needle holes

The results of tests of the single liner bags showed that the combination of 14 oz jute/6 mil liner was only slightly better than the 10-oz jute/4 mil liner and that the fertilizer loss was 40 80+ oz as compared with 1 13 oz with the double liners

The results of the drop tests showed some overall advantage for the double liner system with best performance when the inner liner (4-mil) was closed by tying

This type of closure, however, generally is not looked on with favor by some because the bags are "rounded" and are said to be difficult to stack well The PE liner has less volume because some of the material is "bunched" to permit application of ties Next best results were obtained when the liner was closed by folding The liner did not break but the fold opened after the retaining action of the outer bag was voided by its failure

### Moisture Penetration

The moisture penetration tests showed that when bags of urea were exposed to highly humid conditions, those bags in which the inner liner had been sewn closed with the jute contained wet fertilizer The moisture entered through the needle holes In a 90 day period, at 95% relative humidity and 95° F, about one fourth of the fertilizer was wet

No moisture entered bags with liners closed by heat sealing, tying, or folding It should be pointed out that the use of a double liner is not a safeguard against moisture penetration once it is punctured

A series of tests also was made with single and double PE liners that contained pinholes so that entrapped air would exit the bag under pressure of stacking and thus improve stacking With the single liner bags, moisture entered through these holes as the result of wicking from the jute fiber even when the bags were stacked There was no wetting of the fertilizer in the double liner bags because the pinholes were not in line The outer liner sealed the holes in the inner liner but did not stop exit of entrapped air

### Deterioration of Bag Materials

The fertilizers used in these tests were urea, triple superphosphate, diammonium phosphate, potassium chloride, and ammonium nitrate The data of table 2 show that in these tests, jute was seriously degraded by all the fertilizers and that mechanical strength was reduced by 50 100% Other tests showed that the upper sections of the exposed materials, which became wet with fertilizer salt solutions by wicking, also decreased in strength, but not as much as did the jute that was in direct contact with the fertilizer Further evidence of the detrimental effect of fertilizer salts on jute was indicated by the easy tearing of bags that had been stored in a humid atmosphere with fertilizer salt (urea and triple superphosphate) sprinkled between the bags Such a condition could exist if a bag was broken when being placed in storage or in a ship's hold

Except in one instance, the PP was not degraded by these fertilizers The low value shown for the specimen exposed to diammonium phosphate is believed to be in

Table 1 Summaries of hook and drop tests[a]—50 kg jute/PE bags

| Design | | PE liner[b] Thickness mil | Closure[c] | Hook test: Spillage of fertilizer, oz, from Liner | Hook test: Spillage of fertilizer, oz, from Jute | Drop test: No of drops (8½ ft) to failure Jute | Drop test: No of drops (8½ ft) to failure Liner |
|---|---|---|---|---|---|---|---|
| *14-oz jute/single liner* | | | | | | | |
| J 1 | | 6 | ST | (2)[d] 40 | Nil | (1)[d] 2 | 2 |
| J 2 | | 4 | ST | (1) >80 | 2 | (1) 2 | 4 |
| J 3 | | 6 | TT-BL | (2) 60 | Nil | (2) 2 | 2 |
| *10-oz jute/single liner* | | | | | | | |
| J-4 | | 6 | ST | (3) 65 | Nil | (1) 1 | 1 |
| J 5 | | 4 | ST | (6) 55 | 1 | (11) 1 | 2 |
| J 6 | | 4 | TT BL | (8) 80 | 1 | (5) 1 | 2 |
| J 7 | | 4 | CF | (6) 70 | 1 | (10) 1 | 3 |
| J 8 | | 4 | HS | (–) – | – | (2) 2 | 3 |
| *10-oz jute/double liner (o = outer, i = inner)* | | | | | | | |
| | | Outer liner glued to jute | | | | | |
| J 2A | o | 4 G | ST | (5) 1 | Nil | – – | – |
| | i | 4 | TT BL, CF | | | | |
| J 2B | o | 2 G | ST | | | | |
| | i | 4 | TT BL, ST,CF | (5) 3 | <1 | (5) 1 | 2 |
| J 2C | o | 2 G | ST | (2) 5 | <1 | (3) 1 | 3 |
| | i | 2 | CF | | | | |
| | | Outer liner not glued to jute | | | | | |
| J 2D | o | 4 | ST | (6) 6 | Nil | (7) 2 | 3 |
| | i | 4 | CF | | | | |
| J 2E | o | 4 | ST | (17) 13 | Nil | (3) 4 | 7 |
| | i | 4 | TT BL | | | | |
| J 2F | o | 4 | CF[e] | (15) 12 | Nil | (1) 2 | 4 |
| | i | 4 | | | | | |
| J 2G | o | 4 | ST[f] | (15) 8 | Nil | (2) 2 | 2 |
| | i | 4 | | | | | |

[a]Fertilizer in these tests was urea (45% N)
[b]Liners usually were ½ 1 inch wider than the jute bag The length of the liners generally were 1 inch longer than the jute when closed by sewing and 3 inches longer when closed by tying or folding
[c]ST = sewn, HS = heat seal, TT BL = tipper tie or bar loop, CF = "Canadian" fold (Domax Packaging Co , New Westminister, B C , Canada)
[d]Number in ( ) is number of tests averaged
[e]Both liners folded together
[f]Both liners sewn with jute Moisture entered needle holes when exposed to humid conditions

error, since the literature indicates that PP is resistant to alkaline solutions (pH of diammonium phosphate = 8)

### Inspection of Damaged Bags

During the course of this study, we received from the Industrial Resources Division, USAID, New Delhi, a number of 10 oz and 14 oz jute bags said to have been damaged with hooks while being handled in Indian ports (figure 5) These bags had been filled with various types of fertilizer shipped from the U S , West Germany, Poland, Japan, USSR, and Canada Inspections showed major rips and tears of the type that would result when hooks are used with high pull force (over 90 lbs) such as might be needed to pull bags from under a pile of bagged fertilizer

In tests made at TVA for the purpose of causing tears and rips, it was found that about 90 pounds of pull with a hook, when the bag was not permitted to move, resulted in similar tears in both 14 oz and 10 oz jute bags (figure 6) Loss of fertilizer from such damage cannot be avoided Also, it is pointed out that another factor that would contribute to excessive bag failure is weakening of the jute

**Table 2 Effect of chemical fertilizers on strength of jute and PP bag materials**

(Exposure 5 months at 95% R H , 95° F)

| Fertilizer Material[a] | Mechanical strength (tensile = lb grab method)[b] 10 oz jute[c] | Woven PP[c] |
|---|---|---|
| None | 94 | 109 |
| Urea | 48 | 122 |
| TSP | 0 | 112 |
| DP | 21 | 61 |
| KCl | 58 | 111 |
| AN | 45 | 123 |

[a]TSP = triple superphosphate, DP = diammonium phosphate, KCl = potassium chloride, AN = ammonium nitrate

[b]Tensile tests were made with a Scott (CRT) tester in accordance with ASTM D1682, "Breaking Load and Elongation of Textile Fabrics," Method G, Grab Tests (commercial laboratory)

[c]Textile as for AID specifications SBM 68 16A, February 11, 1969

**Table 3 Summaries of hook and drop tests[a]—50 kg PP/PE bags**

| PE liners[b] Design | Thickness, mil | Closure[c] | Hook test: Spillage of fertilizer, oz, from Liner | Hook test: Spillage of fertilizer, oz, from PP | Drop test: No of drops (8½ ft) to failure PP | Drop test: No of drops (8½ ft) to failure Liner |
|---|---|---|---|---|---|---|
| *Single liner* | | | | | | |
| PP 1A | 4 | HS | (2)[d] 36 | Nil | (7)[d] 2 | 6 |
| PP 1B | 4 | ST | (2) 30 | Nil | (3) 1 | 2 |
| PP 1C | 4 | TT | (2) 48 | Nil | (2) 2 | 2 |
| PP 1D | 4 | CF | (2) 25 | Nil | (2) 2 | 2 |
| *Double liner* | | | | | | |
| PP 2A | o 4 ] i 4 ] | ST | (2) 3 | Nil | (2) 2 | 3 |
| PP 2B | o 4<br>i 4 | ST<br>TT BL | (2) 17 | Nil | (2) 2 | 2 |
| PP 2C | o 4<br>i 4 | ST<br>CF | (2) 1 | Nil | (2) 1 | 1 |
| PP 2D | o 2<br>i 4 | ST<br>TT BL, CF | (4) 8 | Nil | (2) 2 | 2 |

Note N P K fertilizer was 16 16 8 grade, 50 kg polypropylene size for urea was not available

[a]Fertilizer in these tests was granular 16 8 8 NPK

[b]Liners usually were ½-1 inch wider than the jute bag The length of the liners generally was 1 inch longer than the jute when closed by sewing and 3 inches longer when closed by tying or folding

[c]ST = sewn, HS = heat seal TT BL = tipper tie or bar loop, CF = 'Canadian' fold (Domax Packaging Co , New Westminister, B C , Canada)

[d]Number in ( ) is number of tests averaged

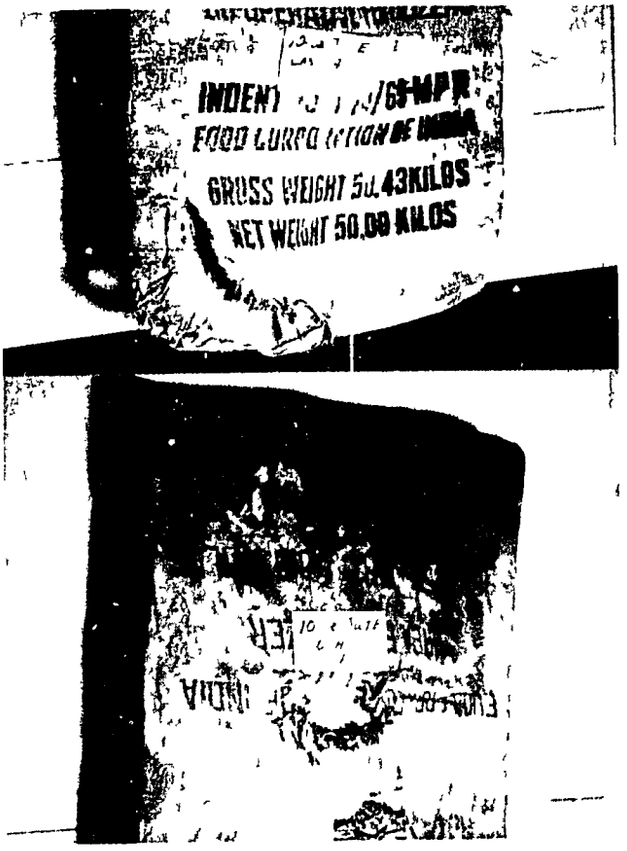



Figure 5 Damaged fertilizer bags received from India
Above—15 15 15 from Canada, 10 oz jute bag with one 4 mil PE liner
Below—Urea from U S , 10 oz jute bag with one 4 mil PE liner

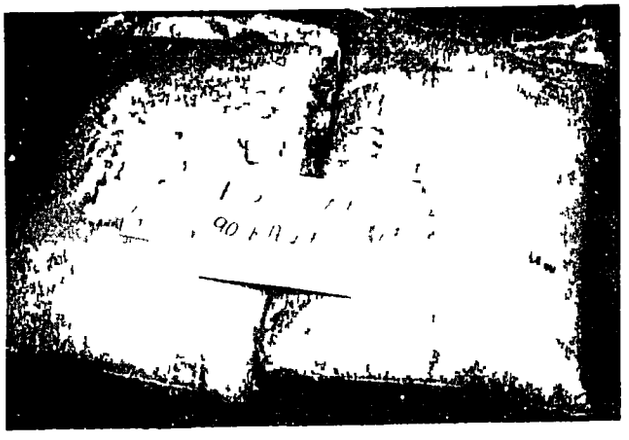


Figure 6 Bags torn in special TVA test (90 lb pull)

as the result of chemical attack by urea, superphosphate, salt water, or other incompatible materials

## RESULTS WITH PP/PE BAGS

Tests were made of the performance of AID approved woven PP bags with PE liners when subjected to the hook and drop tests that have been used with jute/PE bags The 50 kg woven PP overbag is used to a large extent for overseas shipment of fertilizers to countries that do not specify that jute be used Handling in these countries generally is said to be without hooks The current tests were made to obtain information that would be useful should PP bags with PE liners be shipped to countries in which hooks are used These tests, table 3, showed that performance in both hook and drop tests was not greatly different than with the jute overbags In tests at high pull force (90 lbs) the woven PP was much more resistant to tearing and ripping with the hook Another advantage to PP is that it is resistant, as discussed earlier, to deterioration and weakening by fertilizer salt solutions

## ESTIMATED COSTS OF BAGS

In informal discussions with industry, we have obtained the following information relative to costs of 50 kg bags and liners (July 1970)

| Bag or liner | Cost, $ |
|---|---|
| "Standard" 10 oz jute bag with one 4 mil PE liner | 0 32 |
| 4 mil PE liner (pouch) | 0 07 |
| "Stuffing" one pouch into another (double free liner) | 0 01 |
| 2 mil PE liner (pouch) | 0 035 |
| Extra cost of bag with glued liner (excluding cost of liner) | 0 035 |
| Woven PP bag may cost 1 2¢ less than a 10 oz jute bag | |

Therefore, it may be assumed that double liner jute bags of designs J 2C and J 2D, table 1, should cost about 3 5 and 8 0¢ more than the presently approved single liner bag PP bags with a single, 4 mil liner should be about 2¢ cheaper, and those with two free, 4 mil liners (PP 2A, 2B, 2C, table 3) should cost about 6¢ more

As pointed out earlier, closing of the single or inner liner by folding should permit a significant increase in bagging rate over closing by heat sealing or tying, and may result in some economic advantage

## RECOMMENDATIONS

As a result of this study, it is recommended that

1 Test shipments be made of urea in 50 kg jute and woven PP bags of the following designs
   (a) J 2C (table 1)
      10-oz jute, double PE liner
         Outer, 2 mil, glued to jute
         Inner, 2 mil, closed by folding[3]
   (b) J 2D (table 1)
      10-oz jute, double PE liner
         Outer, 4 mil, free, closed by sewing with jute
         Inner, 4 mil, free, closed by folding[3], tying, or heat sealing
   (c) PP 1A (table 3)
      Woven PP[4] with single PE liner
         Liner, 4 mil, closed by folding[3], tying, or heat sealing
   (d) PP 2B (table 3)
      Woven PP[4] with double PE liner
         Outer, 4 mil, free, closed by sewing with PP
         Inner, 4 mil, free, closed by folding[3], tying, or heat sealing
2 The practicability and economic feasibility of using smaller packages, which might be handled without hooks, be investigated
3 Studies be made of the following possibilities for reducing damage of bags and loss of fertilizer
   (a) Establishments of penalties and incentives, according to losses incurred, for crews handling fertilizers
   (b) Development of bags having specific hooking area together with incentives for their use
   (c) The ultimate of eliminating, completely, the use of hooks

Two designs of jute bags with double liners are recommended so that evaluation can be made in actual practice of the merits of having one liner glued to the jute Indications are that gluing will permit the use of liners of lesser weight and lower cost The costs of the recommended bags, J 2C and J 2D, should be about 3 5 and 8 0¢, respectively, more than the cost of the currently used bag with one liner

The PP bags are recommended because they should give better performance They are more resistant to tearing at high pull forces, and are resistant to rot and chemical attack by fertilizers Also, they are less expensive

It is pointed out that testing in the laboratory has been carried as far as is practical without test shipments as recommended or without firsthand observations to determine whether the severity of the tests are in line with what occurs in practice

[3]Liners to be closed by folding should be of such length that outage (length above fertilizer) is equal at least to the diameter of the jute bag

[4]USAID specifications for woven PP fertilizer bags (50 kg)

*Bulletin Y-31* *July 1971*

NATIONAL FERTILIZER DEVELOPMENT CENTER TENNESSEE VALLEY AUTHORITY MUSCLE SHOALS, ALABAMA 35660