PERFORMANCE OF COTTON MODULE COVERS: A SUMMARY OF TESTING AND STANDARDIZATION EFFORTS

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Abstract

The adequate protection of seed cotton stored in modules has long been recognized as important for maintaining the quality of lint and seeds, and for maximizing the performance of the ginning process. Quality preservation in stored modules is dependent on two aspects of that system; the module shape and the water resistance of the protective cover. In 2003, an industry sponsored project was initiated to assess the potential for value loss, assess the performance of commercially available module covers and to develop improvements of the protection system. That project was concluded in 2009, and the results of those studies are summarized here. Those results showed that 50% of modules were formed with a shape that would cause water to collect on the top surface, modules stored with a poor shape and a low quality cover averaged $650 less lint value per module than those with good shape and cover quality, poor protection resulted in reductions of both lint turnout and ginning rate, and new module cover materials tested for ultraviolet and mechanical flexing showed differing performance in resisting water penetration following weathering and repeated mechanical motion. Information from these studies has provided the background for the development of a draft standard on the performance of module cover materials. The proposed standard is described, with the reasoning behind the proposed aspects of the standard. The draft standard will be considered for adoption by the Cotton Engineering committee of the American Society of Biological and Agricultural Engineers in 2012.

Introduction

The development and adoption of the cotton module system was a disruptive technology change for the cotton industry. The ability to decouple the harvest and ginning operations was profitable for both producers and ginners. An underlying foundation of the module system is the premise that the harvested seed cotton could be stored in the modules until ginned without significant degradation of the lint or seed. Years of experience have resulted in two primary lessons learned; 1) storage with no degradation is possible under proper conditions and 2) those conditions are often not maintained, resulting in lower value for cotton seed and lint.

Wet harvest and ginning seasons resulted in concerns over significant problems with wet cotton in modules. These difficulties resulted in the need for research to address the module system and to suggest improved methods that would minimize problems with seed cotton degradation during storage in modules. Multiple research agencies of the cotton industry collaborated to provide sufficient funding to address the problem. A project was initiated at Texas A&M University to consider the problems and identify potential solutions. This document is an overview of the results of that project and a description of a draft standard that has grown out of the data generated by the project. The purpose of this document is to summarize the results of multiple studies and to illustrate how those studies provided the background data for the draft performance standard for cotton module cover material.

Current Status of Seed Cotton Preservation Practices

Module Shape

Since module shape determines whether water will collect on the top of the module or run off, it was important to characterize the suitability of module shapes typically created by producers and custom harvest crews. Six cotton gins were visited during the 2003 ginning season, and observations were made of the condition of modules stored in the module storage lot. Observations were made from each end of a module, and included a determination of whether the cover showed evidence of having water ponded on the surface. At some locations, rainfall had occurred shortly prior to the observations. For some covers, standing water was recorded. In other situations, a residue ring in a depression provided an indicator that water had been standing at some point in the immediate past. For each module, the cover ponding status was assigned, the module number recorded and the characteristics of the cover on the module were recorded.

Observations were made at six gins in Texas to determine the module shape characteristics of current practices and cover type variability (Table 1). Observations were recorded at one Corpus Christi area gin, two Gulf Coast area gins, two Brazos bottom area gins and one El Paso area gin. The module shape data gathered indicated that on average, 50% of all modules observed developed an area that ponded water when rainfall occurred. In addition, the module covers used ranged widely in age. Some covers were new that ginning season, while others were more than ten years old. Since age (older covers are expected to have had greater exposure) is associated with a reduced ability to resist moisture penetration, the use of older covers means those modules were potentially exposed to water infiltration. ***These results demonstrated that the potential for degradation of the lint and seed is great, if the modules were to experience rain events***.

Table 1. Observations of module shape and cover made at Texas gins.

Gin	Total Modules Observed	% Ponded*	Module Cover Range of Years	Rain Event
CC1	297	47	93, 95, 98-00, 02-03	5 days prior
G1	66	47	02	Same day
G2	57	44	95, 98, 00	Same day
BB1	91	65	92, 94-96, 99	1 day prior
BB2	93	47	90-94, 96, 00-02	5 days prior
EP1	42	57*	90-01	No rain
All	646	50	90-03	

* % Ponded was a combination of actual water ponded and depressed areas likely to hold water.

Economic Evaluation Of Seed Cotton Module Protection

At the time this project was undertaken, the cotton industry understood that water damaged seed cotton when stored in modules, and resulted in lint grade degradation. What was not well quantified was the true economic impact of that damage in both quality and cost to the producer and ginner. During this study, a weather event in the Texas High Plains provided the opportunity to assess the influence of module protection practices on profitability for both the producer and the ginner. While this area normally has low rainfall during the harvest and ginning time period, the 2004-2005 harvest and ginning season experienced an extended rainfall event with little wind. Employees of the United Cotton Growers Cooperative gin (located in Levelland, Texas) collected data on the modules and covers to determine damage to seed cotton. USDA classing data were provided for bales ginned from modules that experienced a range of storage conditions. All cotton included in this study was FiberMax picker varieties that were harvested with cotton strippers. Six conditions of cotton storage/ginning were compared. The first condition was cotton harvested, formed into modules and ginned before any snow or rainfall events. Condition two was cotton formed into well-built modules, covered with a “good” module cover and ginned after the rain. Condition three was cotton formed into well-built modules, covered with a “poor” module cover and ginned after the rain. Condition four was cotton formed into poorly-built modules, covered with a “good” module cover and ginned after the rain. Condition five was cotton formed into poorly-built modules, covered with a “poor” module cover and ginned after the rain. After rainfall subsided and soils dried enough for producers to get back into the fields, the cotton on the stalks during the two week rain period was harvested. Condition six was this weathered cotton formed into modules, covered and ginned before any subsequent rainfall.

A well-built module was defined as a module packed to 10 to 14 pounds per cubic foot density, with a crowned top to allow rainwater to drain off of the top, and formed with cotton harvested at the correct moisture content. A poorly-built module is one defined as not having one or more of the above characteristics. A “good” cover was three or less years old. A “poor” cover was older and used multiple seasons (up to 10 seasons). Module shape and cover condition descriptions were determined by the gin employees.

Analysis of the USDA color grades showed a clear deterioration between conditions 2 through 5. Figure 1 shows the change in average lint loan value of a module when compared to condition 1 (harvested and ginned prior to any weather exposure. Condition 2 (well-built module with a good cover) successfully protected the seed cotton from damage, while the lack of a cover with adequate water resistance resulted in approximately $400 in lost value and a poor shape resulted in approximately $200 in lost value.

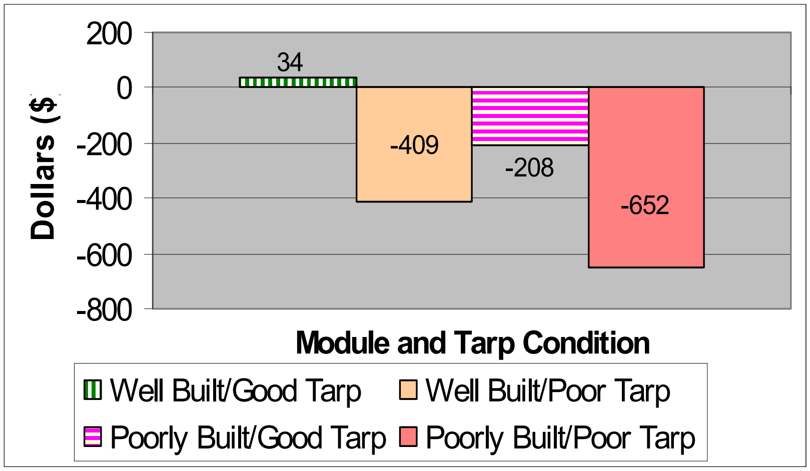

Figure 1. Average change in loan value per module (compared to modules ginned before rainfall events) for combinations of module shape and cover condition.

Besides the losses due to cotton grade reductions, additional losses occur due to poor turnout percentage and gin downtime. Table 2 shows the change in the percentage of module mass captured as lint (turnout) and the ginning rate that was achieved when processing modules of each type. The ginning records were made available for analysis, so the time required to complete ginning of each module was calculated.

Table 2. Impact of Module Storage Condition on Turnout and Ginning Rate

Storage Condition	Turnout (%)	Ginning Rate (BPH)
Well-built module, Good cover	34	42
Well-built module, Worn cover	27	29
Poorly built module, Good cover	31	34
Poorly built module, Worn cover	26	19

These results clearly demonstrated that the economic cost of inadequate protection of seed cotton stored in a module can be significant. While forming low density modules with concave top surfaces and using excessively worn covers will only result in damage if weather events occur, these practices expose the cotton producer and ginner to unnecessary potential loses. The cost of using a worn cover when a significant rainstorm occurs can be 3-4 time the cost of a new cover. ***The economic loses from poor module protection represent a hidden cost that neither the producer nor the ginner can recognize easily. The size of those potential losses justifies a major effort to ensure that all modules have a crowned shape and are protected with high quality covers.***

Water Resistance of Module Cover Materials

Water Penetration Testing Methods

The performance of module covers was based on ability to resist moisture penetration. The cover material is expected to resist water penetration under two different scenarios; rainfall when on a sloped surface, and a depth of standing water when the surface in concave shaped. Two testing standards were identified to evaluate penetration resistance under simulated rainfall and water ponding on surfaces of samples.

The American Association of Textile Chemists and Colorists (AATCC) standard TM 42-2000 Water Resistance: Impact Penetration Test was used for simulating rainfall. The test apparatus was constructed according to standard specifications, with the exception that the angle of the support surface was set at 15° rather than the specified 45°. This change was made to more closely simulate conditions on cotton modules. With the exception of the support angle, the procedure exactly followed the standard procedure. An amount of 500 mL ± 10 mL of deionized water was poured into a funnel attached to a machined spray head. The water fell 24 inches to the sample with a blotter paper backing. The blotter paper was pre- and post-weighed to determine the water amount that penetrated the sample. Figure 2 shows the rainfall simulation test in practice.

Figure 2. Conducting a test of water penetration through a module cover specimen (green material) using the modified AATCC standard TM 42-2000 Water Resistance: Impact Penetration Test

For simulating water ponding on the cover material, the American Society for Testing and Materials (ASTM) standard D 751 – 98 Standard Test Methods for Coated Fabrics, Section 37 Hydrostatic Resistance, Procedure B was followed. The test apparatus was constructed according to standard specifications. This standard was considered an extreme test for resistance to water penetration, as the hydrostatic head of water maintained over the cover material was 1 m. This is a significantly greater head than would be found on a module cover in the field. However, the greater head allowed a measurable amount of water to be collected in a shorter time period. The procedure deviated from the standard recommendation (recording the time required for the first drop of water to penetrate the sample) in that the cover specimen was exposed to the hydrostatic head for ten minutes, and the mass of water accumulated was weighed. This approach gave a great level of discrimination between cover samples with varying levels of resistance to water penetration.

Module Covers Tested

Module tarp manufacturers/distributors donated 36 new covers for testing. In addition, more than 60 used covers were collected from ginners, tarp manufacturers and tarp repair companies. New and used covers included specimens from seven different manufacturers, encompassing a range of materials, styles, construction, damage level and geographic areas of the U.S. Cotton Belt. Table 3 presents descriptions of the covers included in the study. For reasons of confidentiality, the various covers will be referred to by the code letter indicated.

The covers were all evaluated using a light box with high output fluorescent lights. Module covers were characterized according to appearance and damage level. Most new covers were free of serious defect or damage. Used covers were divided into four levels of damage based upon pin-hole density and larger hole occurrence. Damage levels were light, moderate, heavy and abuse. Specimens with varying damage conditions were marked and cut from each cover. At least five samples were taken from each cover. Each of the new covers also was sampled to allow six replications of outdoor weathering tests.

Table 3. Description of covers included in testing.

Cover Code	Material	Construction (Warp x Weft)	Year/Condition/ (Amount)	Color(s)
A	Poly	Woven (8X10)	2003 new (2) 2000 new (1) 2001 used (2)	Tan/White Tan/White Green/White
B	Poly	Woven (12X12)	no year new (1) 1993 used (1)	Green/Green Yellow/Yellow
C	Vinyl	Woven (8X8)	2003 new (1) 2003 new (1) 2002 new (1) 2002 used (3) 2001 used (1) no year used (1)	Green /White Yellow/White Blue /White Red/White Blue/White Green/White
D	Poly	Film	2003 new (3) 2003 used (5) no year used (2) no year used (4)	Gray/Gray Blue/Blue Gray/Gray Green/Green
E	Poly	Woven	1998 used (2) 1995 used (1) no year (1)	Silver/Black Silver/Black Silver/Black
F	Poly	Woven (14X14)	2002 new (2)	Green/White
G	Poly	Woven (8X9)	2001 new (3)	White/White
H	Poly	Woven (8X10)	2002 new (3) 1996 used (1) 1995 used (1) 1995 used (1) no year used (1)	White/White Green/Black Green/Black Blue/Black Green/Black
I	Poly	Woven (9X12)	2002 new (3) 1991 used (2)	White/White Lt.Blue/Black
J	Poly	Woven (12X12)	2002 new (2) 2002 new (1) 2000 used (1) 1998 used (2) 1995G used (1)	White/White Blue/Black Blue/Black Blue/Black Blue/Black
K	Poly	Woven (14X14)	2002 new (1) 2001 new (2) 1999 used (3) 1999 used (1) 1998 used (2)	Blue/Black Green/White Green/White Blue/Black Green/White
L	Poly	Woven (11.5X9.5)	2003 new (3)	Yellow/White
M	Poly	Woven (15X15)	no year new (1) no year new (1)	Green/White White/White
N	Poly	Woven	no year used (1)	Black/White
O	Poly	Woven (12X9)	2001 new (3)	White/White

Simulated rainfall tests on 1126 new and used cover specimen were completed. The means for the specimen conditions of new, light, moderate, heavy and abusive use are shown in Figure 3. The mass of water penetrating the cover increased dramatically with increased use level. Of these five conditions, only the new and light use conditions were not statistically different at a 5% level. The new condition specimen allowed near zero water penetration, while the lightly used covers only allowed slightly more. This result quantifies the expected result that covers perform more poorly as the number of holes and defects increase.

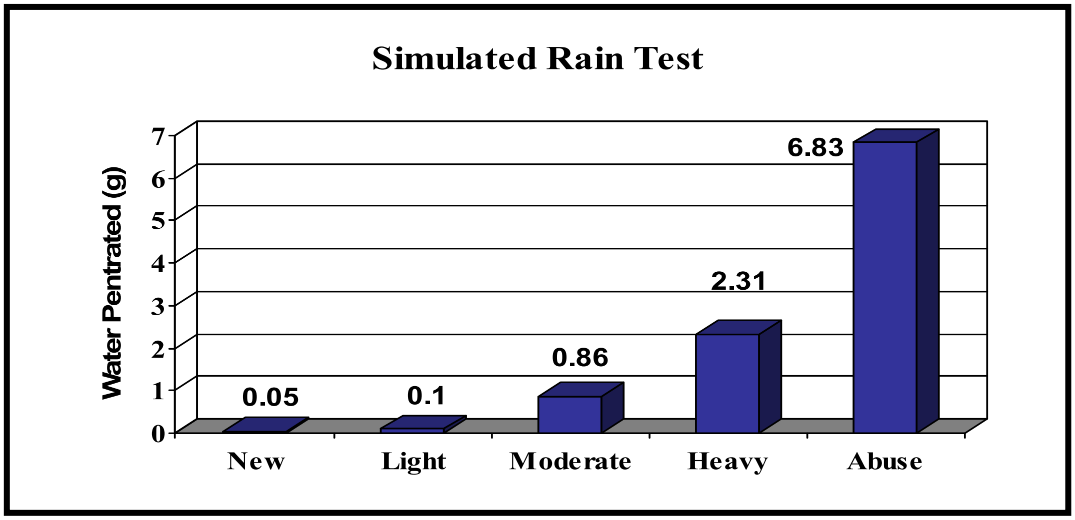

Figure 3. Mean moisture penetration of cover specimen as a function of damage ratings. The values are the mass of water absorbed on plotter paper place under the specimen.

The hydrostatic head test was performed only on the 474 specimen from the new covers and those that were exposed to the weathering test. The analysis of variance for new covers showed no significant difference between covers in mean water penetration. However, this result is somewhat deceiving, as the performance of the various samples from a given cover model could be quite variable. For example, covers C, D and L uniformly had 0.0 g of water penetration, while model A had sample results that varied from 0.0 to 100.9 g. This wide variability between sample performance for covers of the same model and manufacturer occurred frequently. The results for used cover specimens were generally poor, as those had existing pinholes, and the hydrostatic pressure from the one meter head resulted in significant water penetration. This was an expected result.

The water penetration testing demonstrated the degraded performance of the covers as the level of use increased. A used cover rated as moderate use would likely be considered acceptable by most ginners and producers. However, that quantitative evaluation demonstrates that the water penetration rate is sufficiently high that unsafe moisture levels can occur in a module after a typical rain event. ***New covers provide a high level of protection, but that protection is degraded with use, and covers that seem visually acceptable may allow excessive levels of water penetration.***

Performance Evaluation of Module Cover Material

Module covers typically are degraded in performance by one of three sources: exposure to ultraviolet light, mechanical damage from wind motion and inappropriate handling or storage. This research project attempted to evaluation the ability of cover materials to withstand the first two types of damage. No attempt was made to examine man-made damage. The initial work concentrated on the degradation of the covers from ultraviolet irradiation. Following that study, an analysis was conducted to evaluate wind damage.

Weathering Tests

Weathering tests may be conducted by ambient exposure or artificial weathering. For this study, long term ambient weathering was used. The protocol followed ASTM Designation D 1435-99 Standard Practice for Outdoor Weathering of Plastics. Prior to weathering, the specimens were tested with both the rainfall and hydrostatic head procedures. Fifty-six new cover samples, two cotton bale bagging samples and two clear film samples were mounted onto wood racks. Each sample was backed with seed cotton held in place by wire screen. The racks were placed outdoors (Figure 4) about 15 km west of College Station, Texas, (latitude 30° 36´N and longitude 96° 24´W). Temperature, relative humidity and solar radiation were monitored daily by an on-site weather station. Following a three month summer exposure period, the samples were removed from the rack and subjected to the rainfall and hydrostatic head tests. This exposure during the summer months only was continued from 2003 to 2007, for those covers that continued to demonstrate acceptable performance in water resistance.

Figure 4. Cover specimen in outdoor weathering racks.

Table 4 contains the results of the rainfall impact testing. The rainfall test was conducted after each period of exposure. Those models that continued to provide adequate water resistance continued with ambient exposure in the next year. The number in each cell is the average water penetration (g) in the rainfall test following that period of exposure. The total radiant energy over all wavelengths measured during each period and the accumulated energy is indicated in MJ. The UV portion of sunlight (290-400 nm) is 9.8% of the total energy (ASTM G155-05a, 2005). All testing ended following summer 2007. In summer 2003, some samples were removed from testing due to poor performance in hydrostatic tests (data not shown here).

Six models of module tarps were subjected to outdoor weathering for 12 to 15 summer months and allowed little or no water penetration. These models included woven coated polyethylene materials, woven vinyl coated materials, and film polyethylene materials. Two woven polyethylene materials performed marginally with excessive degradation within three to six summer months of exposure. Four woven poly materials performed poorly with less than three months of water penetration prevention. While several models provided adequate performance over an extended exposure period, others degraded quickly. A***t the time that these samples were collected (2003) module cover models sold to producers and ginners provided performance ranging from poor to excellent. The physical appearance of those models did not provide clues that would allow a purchaser to distinguish between the excellent and poor models.***

Table 4. Results of water penetration testing following ambient weather exposure.

Outdoor Weathering Period			S1	S2	S3	S4	S5
Solar Radiation in each period, (MJ/m^2)			2,200	2,100	2,100	2,000	1,910
Accumulated Solar Radiation, (MJ/m^2)			2,200	4,300	6,400	8,500	10,600
Cover Model Code	**Material**	**Construction**	**Average Water Penetration Rate (g/min)^**				
F[+]	Plastic	Woven	0.3[b]				
K[+]	Plastic	Woven	7.6[a]				
M[+]	Plastic	Woven	0.0[b]				
J[+]	Plastic	Woven	0.2[b]				
I[+]	Plastic	Woven	0.0[b]	7.7[a]			
B[#]	Plastic	Woven	0.0[b]				
G	Plastic	Woven	0.0[b]	0.0[b]	0.0[b]	0.0[a]	0.0[b]
H	Plastic	Woven	0.0[b]	0.0[b]	0.0[b]	0.0[a]	13.8[a]
D	Plastic	Film	0.0[b]	0.0[b]	0.0[b]	0.0[a]	0.0[b]
C	Vinyl	Woven	0.0[b]	0.0[b]	0.0[b]	0.0[a]	0.0[b]
A*	Plastic	Woven	0.0[b]	0.1[b]	0.0[b]	4.5[a]	
L*	Plastic	Woven	0.0[b]	0.0[b]	0.0[b]	5.1[a]	
N[+]*	Plastic	Woven	0.0[b]	0.2[b]	24.9[a]		

^Values in same column with same letter indicate no significant difference in mean.
[+]Six cover models were removed from study after Summer 1, 2 or 3, respectively, due to poor performance in rainfall or hydrostatic tests.
[#]One cover model was removed from study after Summer 1 due to inadequate number of samples.
*Three cover models added to the study during the Summer 2 period.

Wind Tunnel Testing

Wind is the second mode of cover degradation that was studied. The mechanical motion created by the wind when whipping the cover material can result in the breakdown of the coating and torn material. No existing standard testing method was identified that was adequate to simulate the influence of wind on module cover material. An initial testing effort was undertaken using module covers cut down to fit a simulated module placed in a wind tunnel. A rectangular box covered in foam was used to simulate the module shape, and a section of cover was fastened to the sides in a manner to replicate the function of the cover belt with side tie-downs. The wind speed over the surface of the cover was measured using a pitot tube. Four covers were tested in the wind tunnel till break down (i.e. allowed an average of 250 mg of water to penetrate per site in a bucket test conducted for one hour). The bucket test was similar to the hydrostatic head test method, but was suitable for non-destructive testing of areas on a large section of cover.

A total of four covers were tested in this method and breakdown characteristics of the covers were plotted. Table 5 describes those covers. The change in moisture penetration resistance was measured with the bucket test as a function of wind run (wind speed x time of exposure). Wind speed control was difficult at the lower speeds of the tunnel, but the speed over the cover was approximately 96 kmph (60 mph).

The curves in Figure 5 show that there was a large difference in wind run distance before excessive degradation was experienced. Since there was only one sample for each cover type used, a statistical significance was not possible, but the large difference in the curve shapes indicated that there was a difference between the performances of these cover models. K1 and K2 were the same model, but K1 was obtained as a used cover, so the previous wind exposure was unknown. The covers for this initial testing were obtained for the earlier ambient weathering exposure.

Table 5. Description of the covers used in initial wind tunnel testing.

Model code	Year Manufactured	Brand	Material	New/Used	Characteristics
I	2002	Woven	Poly	New	1 defect Few Cracks
G	2001	Woven	Poly	New	Few Cracks
K1	Unknown	Woven	Poly	Used	Cracks/holes increases across cover
K2	2001	Woven	Poly	New	Few Defects

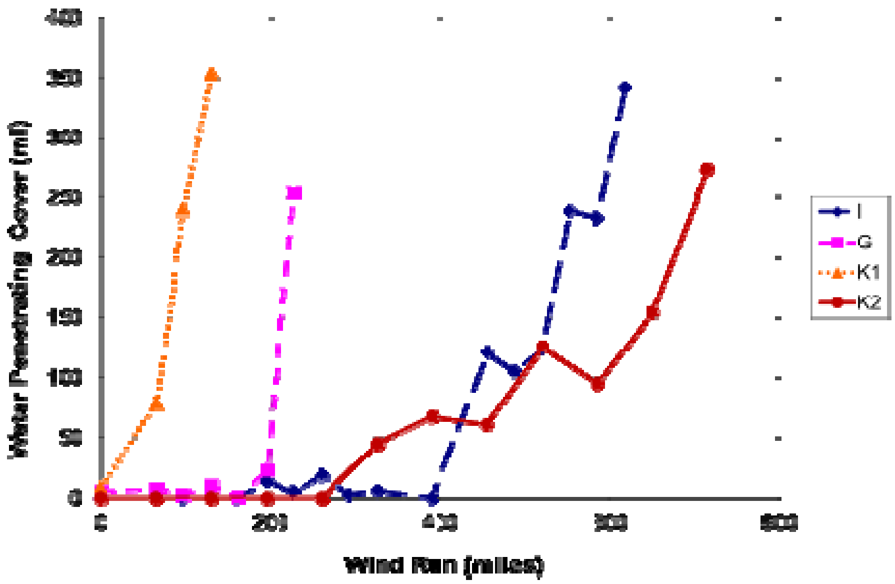

Figure 5. Performance in resisting water penetration for module covers exposed to wind in a wind tunnel.

The results of this initial work showed two major points. First, similar to the performance in ambient weathering, cover models differ in their ability to resist moisture as a function of wind exposure. Second, this testing method required exposure for an extended period of time (potentially up to 12-15 hours of tunnel time. Time and labor requirements needed to obtain statistically valid results were not supportable with the project funding levels. An attempt was made to test multiple smaller specimens simultaneously, but that approach was not sufficiently repeatable to obtain reliable results. In addition, the longer term goal of a standardized performance measure for module covers made the use of wind tunnel testing problematic. Most testing laboratories would not have the ability to conduct wind tunnel tests on cover materials, plus the time and labor requirements would make the evaluations expensive to perform.

Mechanical Flexure Testing

Degradation of cover materials due to mechanical manipulation or motion is the anticipated mode of failure for module covers that degrade with wind exposure. Multiple standards for mechanical flexing or manipulation have been developed. Of those, ASTM F 392 – 93: Standard Test Method for Flex Durability of Flexible Barrier Materials was selected as the most appropriate standard to simulate wind damage. The Flex Durability standard is based on a mechanism, called a Gelbo Flex Tester, which uses a twisting motion of the sample to mechanically flex the barrier materials. Figure 6a shows the crank arm of the Gelbo Flex Tester, and 6b shows a sample mounted on the mandrels of the machine. For these tests, new sample covers and cover materials marketed in the 2008 cotton harvest season were obtained from manufacturers. Table 6 gives the descriptions of the cover materials. The cover codes used for this testing did not represent the same cover models as described in table 3.

(a)

(b)

Figure 6. (a) The crank arm of the Flex Testor was set for the longest stroke. (b) The cover specimen was mounted to the mandrels and the crank stroke would extend and rotate the right mandrel to create the flexing action. The left mandrel is fixed.

Table 6. Module cover materials used in flexure testing.

Cover Code	No. samples tested	Material	Construction (Warp x Weft)	Manufacturing Location
A	9	Plastic	Woven (10x8)	Domestic
B	3	Plastic	Woven (11x11)	Foreign
C	9	Plastic	Woven (9x9)	Foreign
D	9	Plastic	Woven (8x8)	Domestic
E	3	Plastic	Woven (13x13)	Domestic
F	3	Plastic	Film	Domestic
G	6	Vinyl	Woven	Domestic

Using the manufacturer supplied template for the Gelbo apparatus, test specimens were cut from module cover to a sample size of 216 x 279 mm (8.5 x 11 in.). Samples were randomly located on the cover material. The specimens were mounted between the mandrels and flexed for a set of 4000 cycles. Following the 4000 cycles, the cover sample was removed from the tester and the rainfall impact test was performed. After conducting the rainfall impact test, the specimen was placed back on the flex tester, but in reversed orientation so that the cover top surface was facing inward. This action alternated the direction of flexing so that a bias in one direction from the twisting action did not occur. This pattern was repeated until the two gram threshold limit of water penetration was exceeded. After the first 8000 cycles, subsequent flexing periods were limited to 2000 cycles to improve the sensitivity to the point of excessive degradation.

Rainfall impact testing was performed using the AATCC TM 42 standard in a manner identical to its previous use with the UV exposed cover samples. The water impact was always on the top surface of the specimen. The specimen size necessary for the flex testing was somewhat larger than specified for the TM 42, but they were still compatible with that test method.

The values obtained from the flex test and rainfall test have been recorded in Table 7. These covers represented both domestic and foreign manufactured materials from four suppliers. The group included coated woven polyethylene, polyethylene film and vinyl coated woven polyethylene. Three tests were performed on samples from a given cover. Some models had only one cover available, and three samples were taken from that one. For a given cover, the minimum and the maximum number of cycles before exceeding 1 grams of water penetrating are shown. The mean is calculated from the three samples on each cover. The range of values for a single model can be taken by considering the entire group. The film cover (F) did not experience any water penetration, but the film delaminated after 26-48,000 cycles when testing was ceased. For that reason, 24,000 cycles was considered the failure point. The first vinyl coated cover specimen was tested to 96,000 cycles with no water penetration, and testing was stopped. Subsequent specimens were only tested to 48,000 cycles, but had no water penetration.

Table 7. Number of cycles of flexing experienced before water penetration exceeds limits.

Cover Code	No. samples tested	Average No. Cycles before 1 g	Minimum No. Cycles before 1 g	Maximum No. Cycles before 1 g	Number samples >=12000 cycles	Number samples >=16000 cycles
A	9	13800	8000	22000	7	5
B	3	20667	18000	22000	3	1
C	9	13222	10000	18000	6	3
D	9	14444	12000	16000	9	5
E	3	15333	12000	18000	3	2
F	3	24000	24000	24000	3	3
G	6	48000	48000	96000	6	6

The data collected in the initial wind tunnel testing and the flexure tests illustrated similar progression of degradation. Initially, the cover experienced mechanical motion and continued to prevent water penetration. After a period of flexing or motion, water would begin to penetrate the cover material. Once that degradation began, the increase in water penetration occurred with fewer additional cycles or time in the wind. These curves of slow change, but rapidly increasing penetration with greater exposure are also similar to the weathering performance. ***While the data obtained in these studies cannot predict directly performance in wind, the similarity of the breakdown patterns gives confidence that the mechanical flexing is a reasonable substitute and one that can be repeated at reasonable cost in testing laboratories.***

Proposed Standard for Performance of Module Cover Materials

A subcommittee of the ASABE PM-27/7/3 Cotton Engineering committee was charged with generating a draft standard that would establish a minimum level of performance for cotton module cover materials. That draft document is designated as *X615 - Cotton Module Cover Material Performance*. The drafting committee was made up of PM-27/7/3 members and other interested individuals representing manufacturers of module covers and the ginning industry. A copy of the complete standard draft can be obtained from the authors or from ASABE. The description following is intended to describe the important aspects of the draft standard.

The scope of the standard is limited to the performance of the materials used in the top surface of a module cover to resist water penetration. The standard specifies procedures for selecting specimens for testing of water penetration and exposure to mechanical flexure. The standard is based upon the use of the ASTM F 392 Test Method for Flex Durability of Flexible Barrier Materials to provide mechanical manipulation of the material, and AATCC TM 42 Water Resistance: Impact Penetration Test to measure the amount of water that penetrates the materials. Modification of both standard found to be useful during testing at Texas A&M (described earlier in this document) are included as part of the draft standard. Water resistance is to be measured before and after flexing of the material. A flexing limit of 12,000 cycles is proposed in the draft. 12000 cycles was selected based on the test results described above. This number was judged to be a reasonable value that allowed a distinction between acceptable and superior performance. Two levels of performance (acceptable and superior) are allowed under the standard so as to allow the market to determine appropriate performance for covers. One gram of water was selected as the threshold for acceptability based on the calculated effect on moisture content of the seed cotton. The rainfall exposure of the TM42 test is approximately 30 seconds. When considering a four hour storm, a penetration rate of one gram/30 sec. would result in an increase in seed cotton moisture content from 8 to 26% if the water was confined to the top two foot layer of the module. While that is well above a safe moisture level, the one gram level was judged to be a compromise value. Table 8 duplicates the performance specifications in the draft standard.

Table 8. Module Cover Material Specification Requirements

Characteristic	Requirements, minimum	Section
Water repellency after flexure exposure	Acceptable – minimum of 6 of 9 specimens allow less than 1 g of water to penetrate at 12000, and the specimen must retain its physical integrity (i.e. no rips, holes, delamination etc.) Superior – 9 of 9 specimens allow less than 1 g of water to penetrate at 12000, and the specimen must retain its physical integrity (i.e. no rips, holes, delamination etc.)	7.4

The draft standard incorporates only the mechanical flexure testing for degradation of the cover material. In discussions within the drafting subcommittee, the decision was made to not include the weathering test. If weathering were to be included, either the ambient exposure or artificial weathering would have to be the basis for that test. The ambient weathering method requires a long period of exposure for high performing materials. For this standard to have utility for the industry, the testing must be concluded in a reasonable period of time (weeks, not months or years) and at reasonable expense. The alternative would have been the use of artificial weathering machines, but no background data for weathering cover materials in those machines were available. For these reasons, the committee determined that proceeding with the flexure test only was the most appropriate approach. If future data on artificial weathering becomes available, the standard can be amended.

The standard is intended to be suitable for any type of material a manufacturer may select for use in a cover. The standard does not dictate the type or fabrication of the top cover material used. There is no intent that every different cover model must be tested. If material from the same manufacturer with identical specifications is used for different cover models or for lots manufactured over multiple years, the results of the performance test on that material can be used as documenting the performance of each of the cover models. However, the materials must be tested at least every four years as a check against gradual changes in the performance of the material formulations. The draft standard specifies that sufficient details on the fabrication of the top cover material are needed to determine when the formulation and supplier differs from previously tested materials, but not so much as to reveal competitive advantages for a manufacturer. Label requirements are included to provide the cover purchaser with detail on the cover characteristics.

One concern was the cost of performing the specified tests to determine if a material would meet the standard. A proposal for testing one cover material in compliance with this draft standard was requested from a testing firm. The total costs for both flexure and water resistance testing was $2144.

The description of the proposed standard is current as of January 3, 2012, but changes may be made in response to comments during the balloting process, or the entire standard could be rejected. Contact ASABE or the authors to obtain the current status of the standard.

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References

AATCC Test Method 42. 2003. Water Resistance: Impact Penetration Test. American Association of Textile Chemists and Colorists. Research Triangle Park, NC.

AATCC Test Method 127. 2003. Water Resistance: Hydrostatic Pressure Test. American Association of Textile Chemists and Colorists. Research Triangle Park, NC.

ASTM D 751. 2003. Standard Test Methods for Coated Fabrics. ASTM International. West Conshohocken, PA.

ASTM D 1435. 2003. Standard Practice for Outdoor Weathering of Plastics. ASTM International. West Conshohocken, PA.

ASTM G155-05a. 2005. Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Nonmetallic Materials. ASTM International. West Conshohocken, PA.