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IMPROVEMENT OF COT COVERS

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by

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FOREWORD

Under the stress of wartime urgency, many significant improvements were made in Quartermaster items as the need was indicated by field conditions. However, for the most part wartime developments were based upon hasty empirical investigations of immediately available materials. When peace was restored an opportunity was afforded to review much of this work and to establish where necessary a more comprehensive research program based upon sound engineering analysis.

A good example of the added benefits to be secured by supplementing a short-term investigation by a more fundamental study is provided by the Army's program to improve the serviceability of cot covers. Initial interest in this item was aroused early in the war when reports were received that premature cover failures were occurring in the field at an alarming rate. A short study of the problem by Quartermaster technicians resulted in the recommendation of a new fabric and modified cover pattern design which considerably improved the wear life of the item.

After the war, the cot cover was studied carefully from an engineering standpoint, and the specific reasons for failure were established. On the basis of this work, further changes were made in the cover design and new fabrics were adapted which would be best suited to withstand the peculiar service actions to which cot covers are normally subjected. The entire investigation is described in this report in some detail, and it is expected that the results obtained will point the way to the adoption of a cot cover with maximum resistance to service failure.

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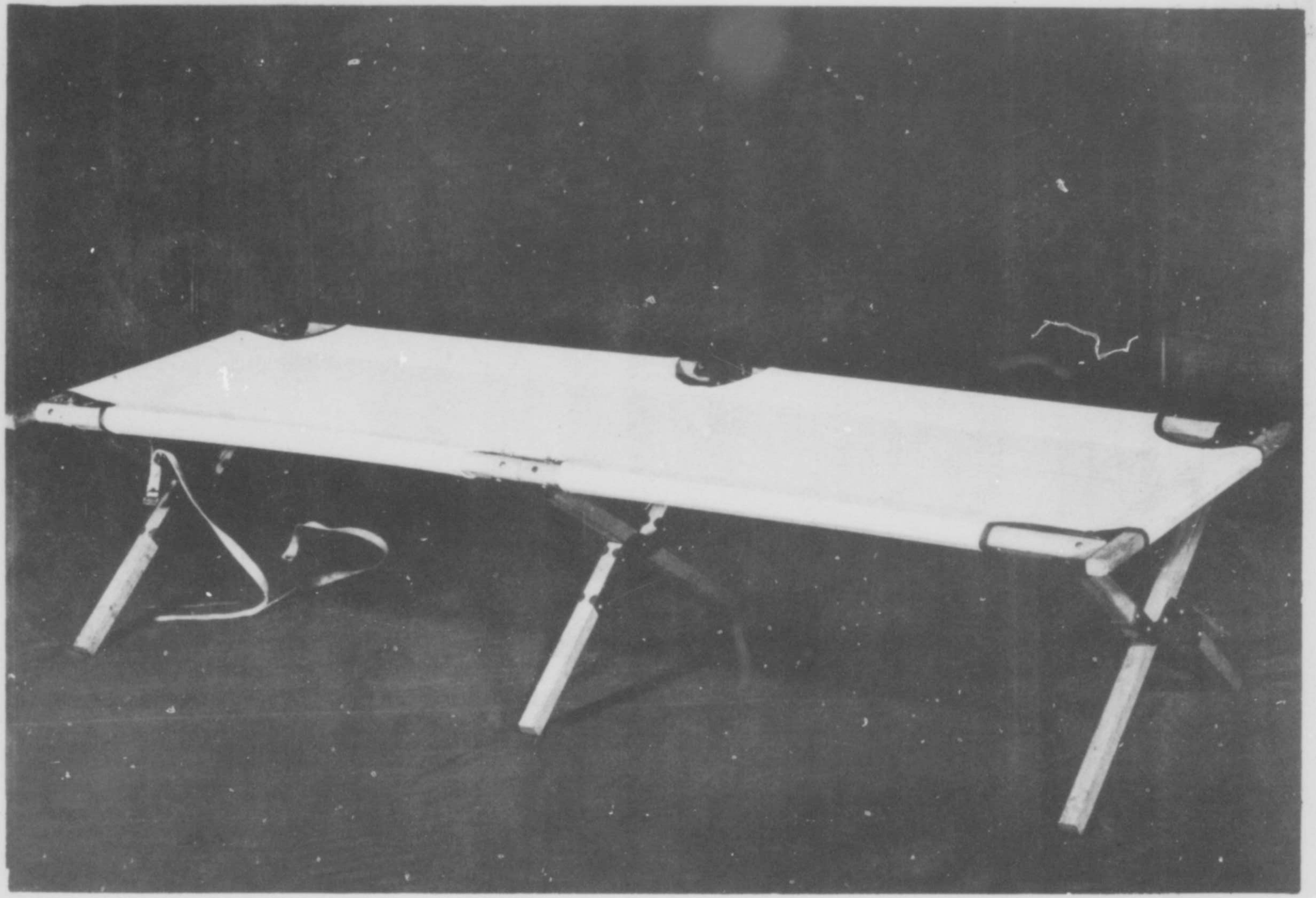

FIG. 1.   ARMY CANVAS FOLDING COT

I. INTRODUCTION

All past experience has shown that the canvas cover of the standard Army folding cot is incapable of withstanding the rough field usage to which the item is normally subjected, causing a serious lack of balance between the service life of the cover and that of the frame. Procurement records reveal that over 50 per cent more covers than frames were required during World War II, extra covers costing more than $18,000,000. In addition to this replacement cost must be considered a heavy expenditure of money as well as time and materials used in field-repair operations. One post quartermaster, (1)* for example, reported that an average of five covers were repaired for each one considered unsalvagable.

Salvage surveys(1,2,3) show that the great majority of covers were destroyed by premature breaks in the fabric or thread at critical pattern areas, and not by normal field wear. Even in the Southwest Pacific Theater, where microbiological degradation is normally the primary cause of loss of cotton fabric utility, a survey(3) showed that over 70 per cent of the discarded covers were salvaged, not as a result of mildew and rot, but because of repeated mechanical failures at certain weak sections of the pattern. The development of a practical cover of optimum durability is therefore contingent upon elimination of these structural weaknesses. To perform such work efficiently and effectively, a full appreciation is required of the influence of cover design and fabric properties on cover serviceability.

This report is the record of a developmental study undertaken by the Quartermaster Corps with the following ends in view: (1) the design of a cover with the greatest possible structural durability, thus effecting reductions in procurement costs as well as in the time and expense of replacement and field-repair operations; (2) the adoption of a lighter, less expensive cover material than is now specified; and (3) the collection of engineering data which can be used as a basis for intelligent substitutions of critical materials in periods of emergency.

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* Numbers apply to references at the end of the report.

II. PRECEDING WORK

The serious shortcomings of the cot cover were realized by the Quartermaster Corps as early as 1942, when extensive surveys of the canvas industry were undertaken as a basis for selecting a superior cover fabric and pattern design. Wartime urgency permitted only an empirical approach to the problem and necessitated adoption of the best available commercial fabric on the basis of brief simulated-service tests. These tests also made it evident that the addition of a reinforcing collar(1) to the center cutout section of the cover appreciably improved its resistance to impact and the pattern design was accordingly modified to include this reinforcement. This empirical program, however, offered no basis for logical substitution of critical materials or development of a more efficient cover fabric or design.

With the lessening of procurement urgency toward the end of the war, the Research and Development Branch of the Office of the Quartermaster General authorized, in June 1945, a project to improve the durability of cot covers. The early stages of the program, carried out at the Jeffersonville Quartermaster Depot, involved the development of a laboratory impact tester. This apparatus was used in rating cot covers made of various commercial fabrics selected for such properties as high breaking strength, high tearing strength, low weight, or successful performance in other fabricated items. Transfer of this research activity to the Philadelphia Quartermaster Depot late in 1945 necessitated a temporary suspension of this work.

III. INTEGRATED RESEARCH PROGRAM

The improvement in cover durability which resulted from wartime empirical studies gave promise that still greater enhancement could be achieved through an engineering study of the cover as a composite functional unit. Accordingly on 30 July 1946, after the organization of Quartermaster research on a peacetime basis, reactivation of the project was approved under the title of "Improvement of the Serviceability of Cot Covers," and assigned to the Textile Research Laboratory, Philadelphia Quartermaster Depot. After a reorganization of this laboratory was completed and work on other projects of higher priority was accomplished, a full-scale investigation was undertaken in September 1947, in accordance with the following plan:

Principles of Cover Design. Modification of the elements of cover fabrication (including cutout design, stitching type and location, and cover dimensions) and substitution of findings were to be considered as a means of improving cover durability.

Principles of Fabric Structure. Fabric properties, such as breaking and tearing strength, elongation, and elasticity were to be studied to determine their influence on cover serviceability. Different fiber types, as well as variations of the fabric structure were to be employed in controlling the above fabric properties.

Testing and Evaluation. Essentially three forms of evaluation were to be employed in this study: (1) determination of the functional efficiency of the finished cover by means of the laboratory impact tester designed to simulate service use, (2) measurement by standard laboratory methods of individual pattern and fabric constructional characteristics which influence cover serviceability, and (3) the corroboration of these laboratory results by service testing.

IV. METHOD OF INVESTIGATION

The primary purpose of this investigation was to improve cover durability without a consequent impairment of other properties which lend utility to the item. Therefore, the critical test for experimental covers was one which simulated the severe impact loading which is normally the primary cause of failures in field use. Secondary considerations were sag resistance which contributes to comfort, and launderability which influences the fit of the cover on the frame.

Laboratory Impact Apparatus. The reliability of the apparatus developed at the Jeffersonville Quartermaster Depot was authenticated by a matching of the failures it produced with those resulting from service use[1,2,3]. In all instances, the failures occurred in the center cutout area of the covers (Figure 2). The marked similarity noted between field damages and the type produced by the laboratory apparatus is evident in Figures 3, 4, 5, and 6. Refinement and mechanization of the original apparatus produced the machine shown in Figure 7. Later, the

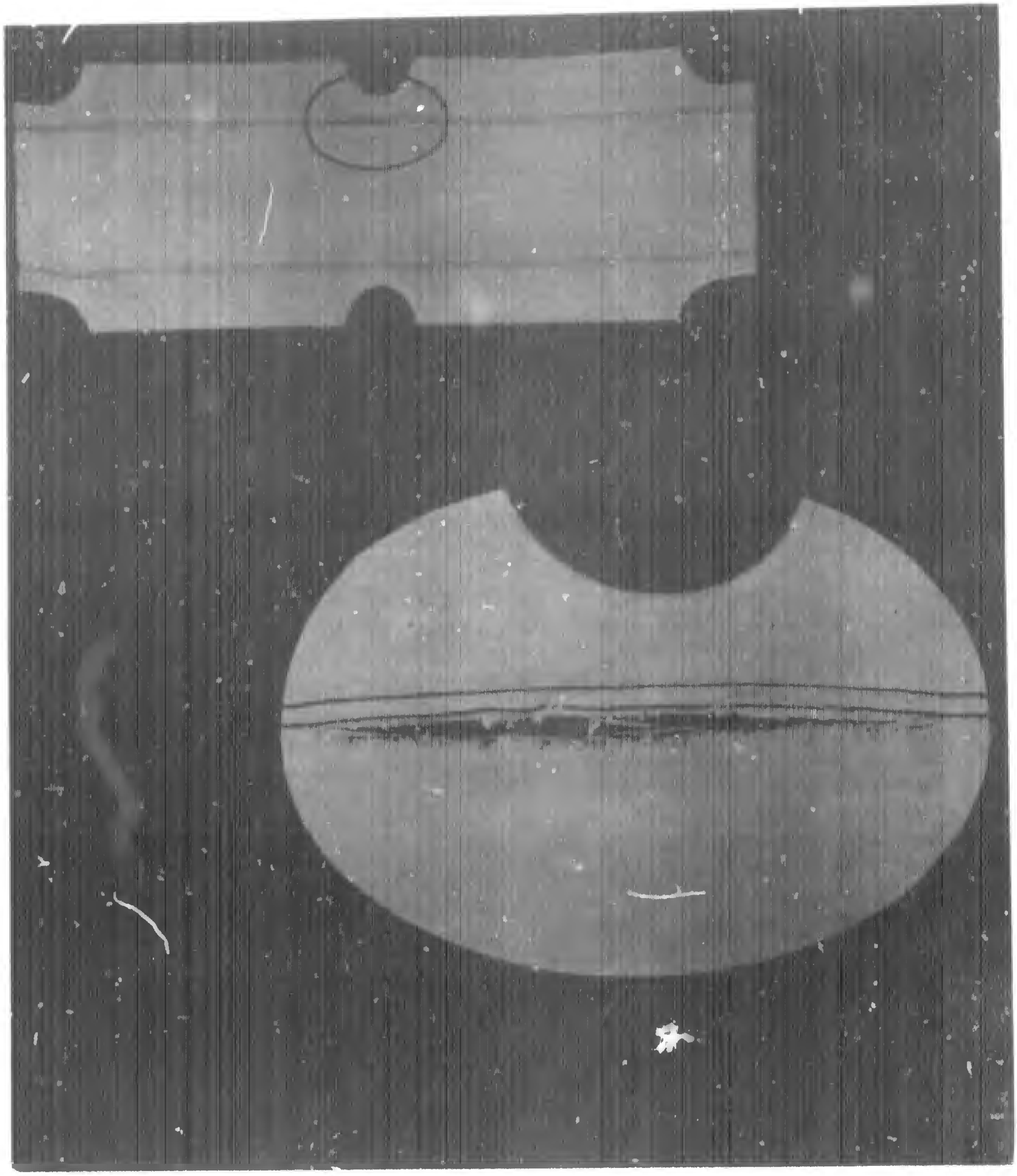

FIG. 2. LOCATION KEY FOR CENTER CUTOUT FAILURES

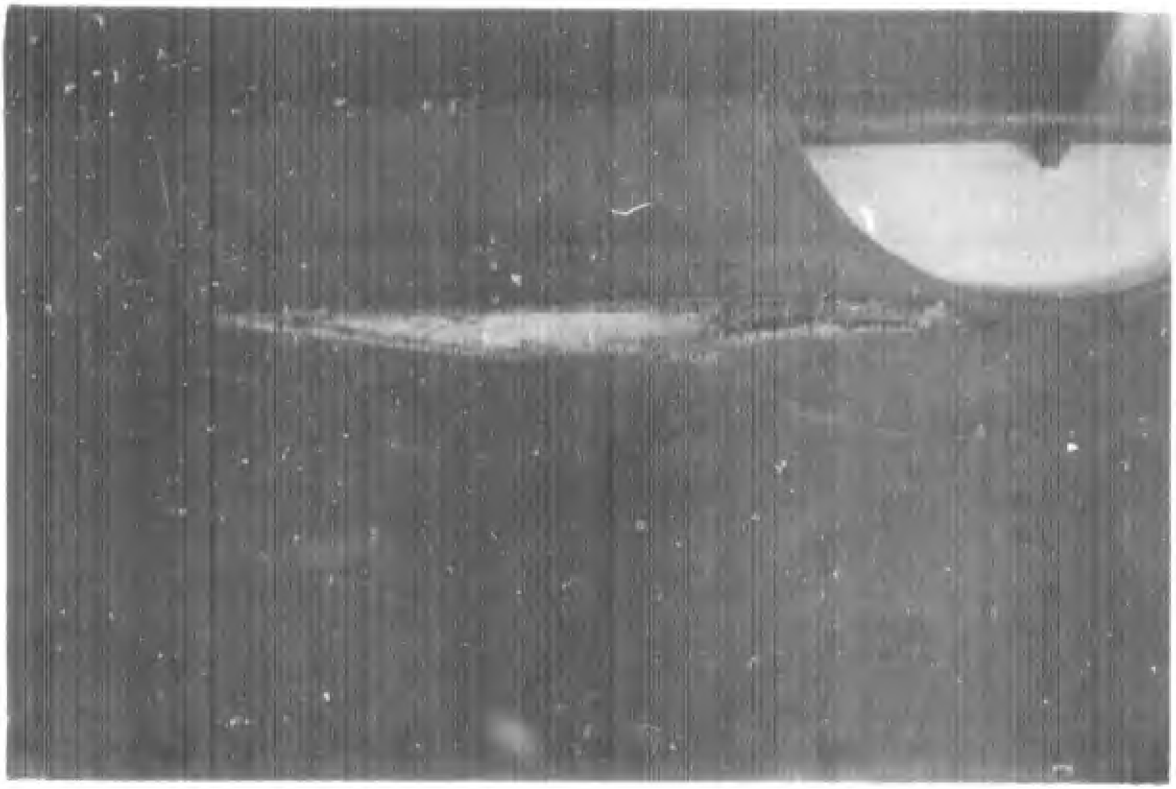

FIG. 3. SERVICE FAILURE (STOCK ITEM, NO. 4 DUCK)

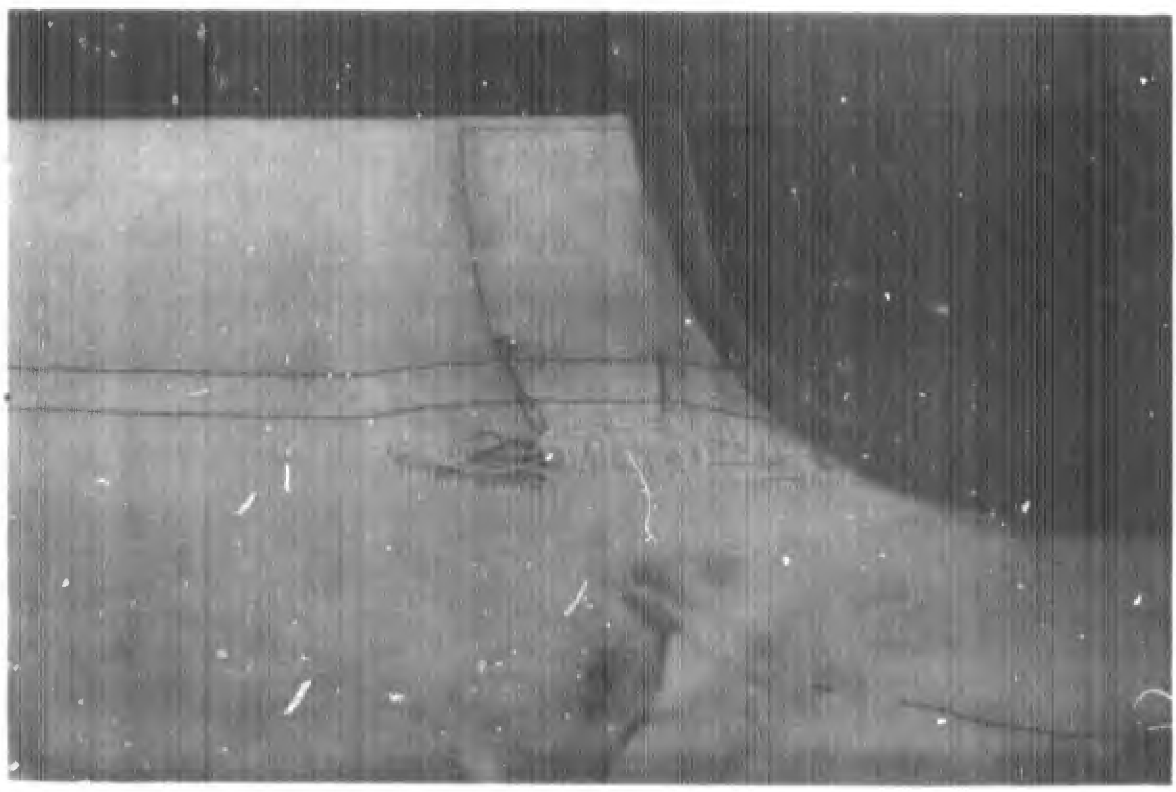

FIG. 4. LABORATORY TEST FAILURE (STOCK ITEM, NO. 8 DUCK)

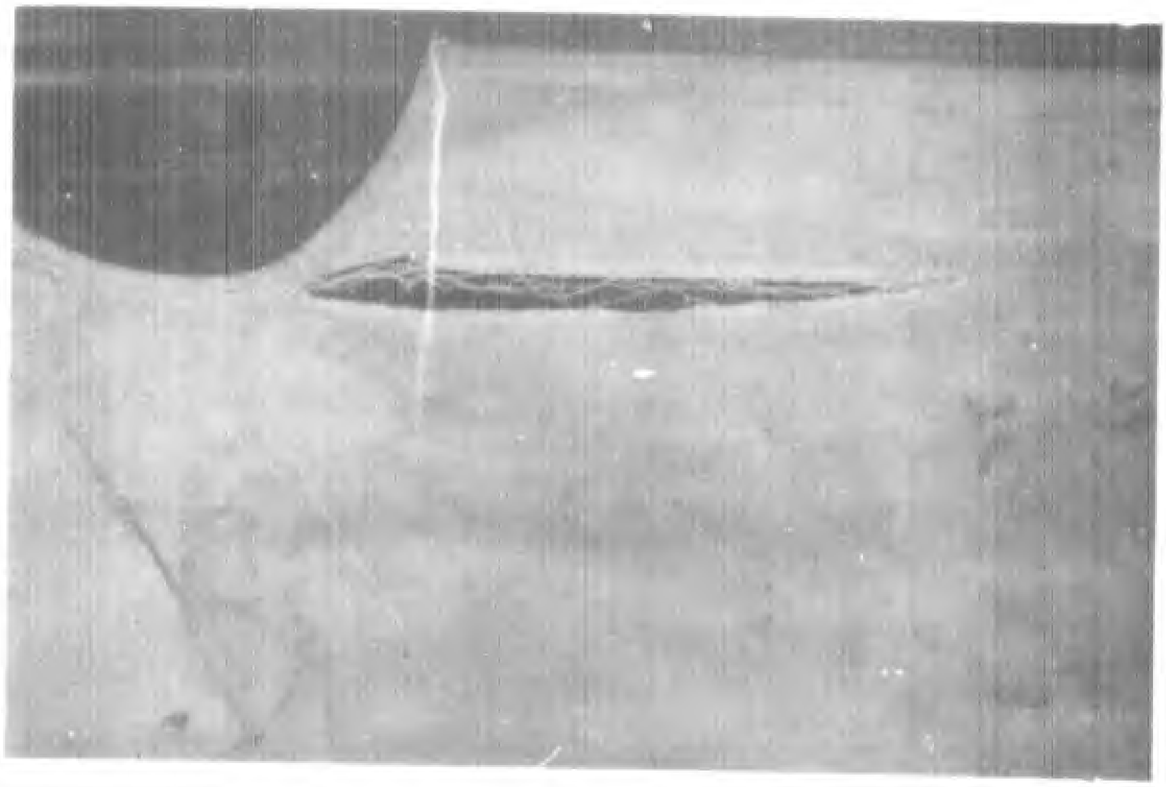

FIG. 5. SERVICE FAILURE (STOCK ITEM, 16-OZ. FLAT DUCK)

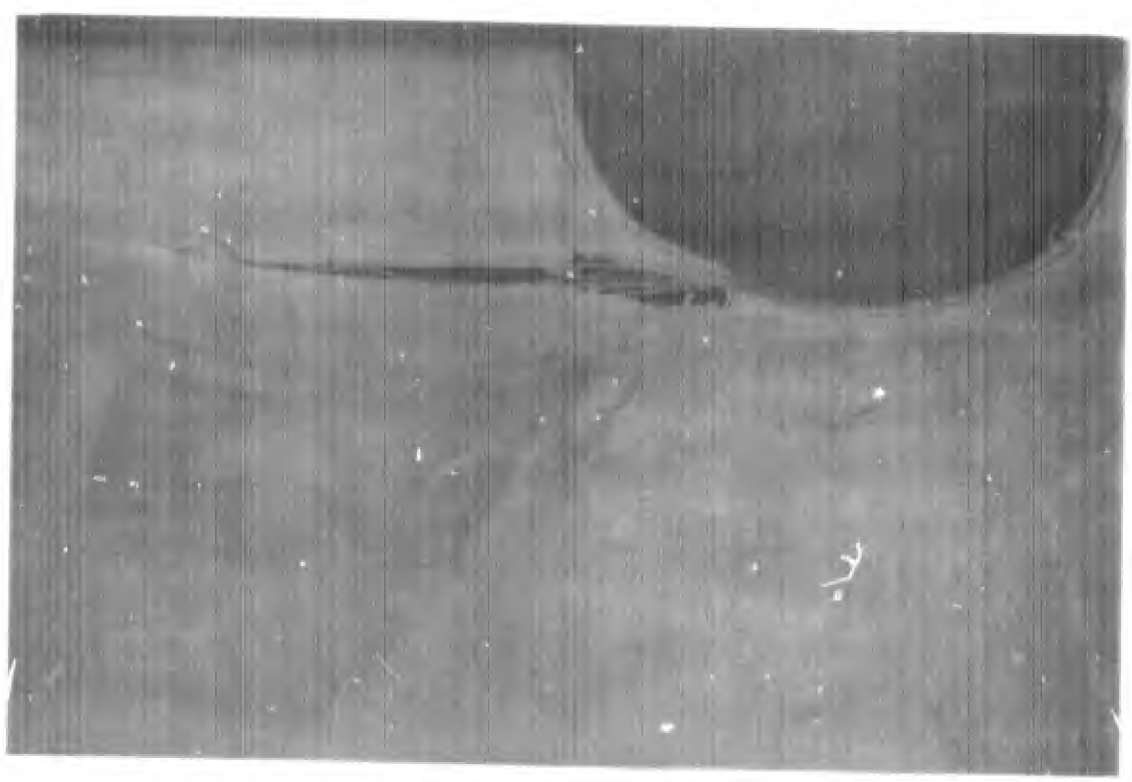

FIG. 6. LABORATORY TEST FAILURE (STOCK ITEM, 16-OZ. FLAT DUCK)

FIG. 7. LABORATORY IMPACT AND SAG TESTER (210-LB. WEIGHT)

FIG. 8. LABORATORY IMPACT AND SAG TESTER (120-LB. WEIGHT)

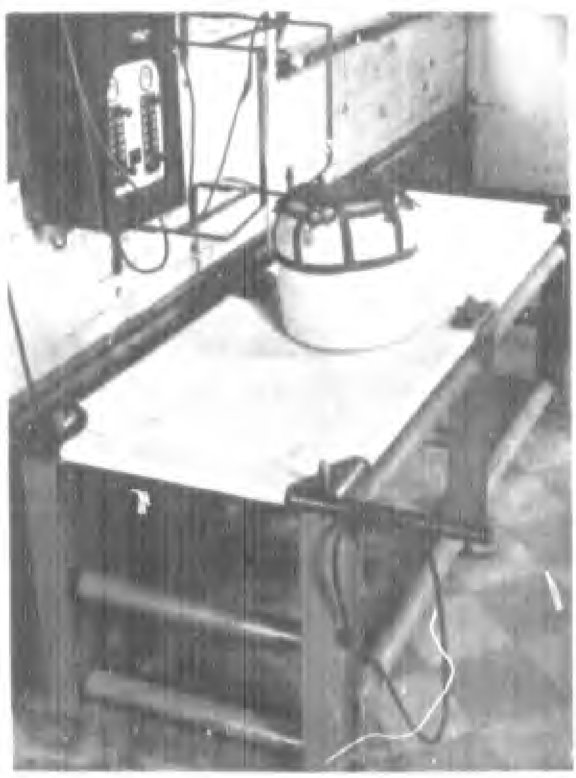

FIG. 9. LABORATORY IMPACT AND SAG TESTER (WEIGHT IN IMPACT POSITION)

210-pound impact weight of the machine was replaced by a smaller one weighing 120 pounds (Figures 8 and 9) because of the greater sensitivity provided by the latter. The machine permitted cover testing by means of two loading actions, impact and static. The former consisted of dropping the weight by an electro-magnetic release from a predetermined height to the test cover mounted on a rigid metal frame, and the latter of allowing the weight to remain on the cover for a fixed period.

Fabrication of Test Covers. The covers were made by the equipment and methods of a conventional canvas shop, but each fabrication process was closely controlled to insure uniformity and proper workmanship. Each cover was hemmed to dimensions which would allow a firm fit when mounted on the frame. The sharp curvature of the center cutout sections required the use of a properly designed binder-hemmer (Figures 10 and 11) which folded the web binding evenly, thus permitting a secure stitching of the two components.

Laboratory Test Procedure. The number of blows required to produce complete failure of the cover on the impact device was adopted as a measure of impact durability. A cyclic impact was selected because it simulated in principle the repeated loadings to which the covers are subjected in service. Originally the weight was dropped from an 8-inch height but as covers of increasing durability were developed it became necessary to increase this height to 12 inches.

The sag properties of experimental covers were also tested on the impact apparatus. These determinations included (1) extensibility under load and (2) recovery from sag after removal of load. Cover extensibility is expressed as the distance (in inches) the cover sags below the level of the test frame when weighted by the 120-pound bag. Two measurements have been chosen as expressions of this property: (1) the amount of sag noted just prior to fabric failure as a result of a series of impact blows, and (2) the amount of sag noted after 24 hours of static loading with the 120-pound weight. Observation of cots in actual use revealed that the maximum cover sag permitted by the frame construction corresponded to a measurement of 3-3/4 inches on the laboratory impact apparatus. The ability to recover from sag (elasticity) was ascertained by subjective examination of covers which had sustained ten per cent

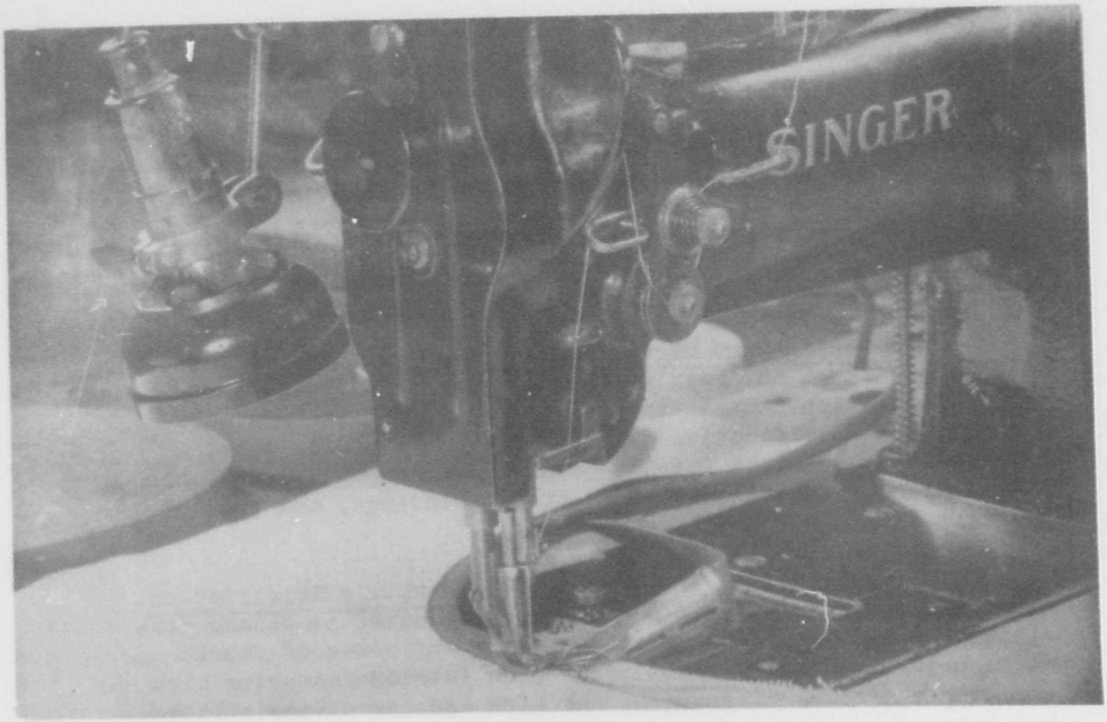

FIG. 10. SEWING ATTACHMENT FOR BINDING AND HEMMING CENTER CUTOUT (IN OPERATION)

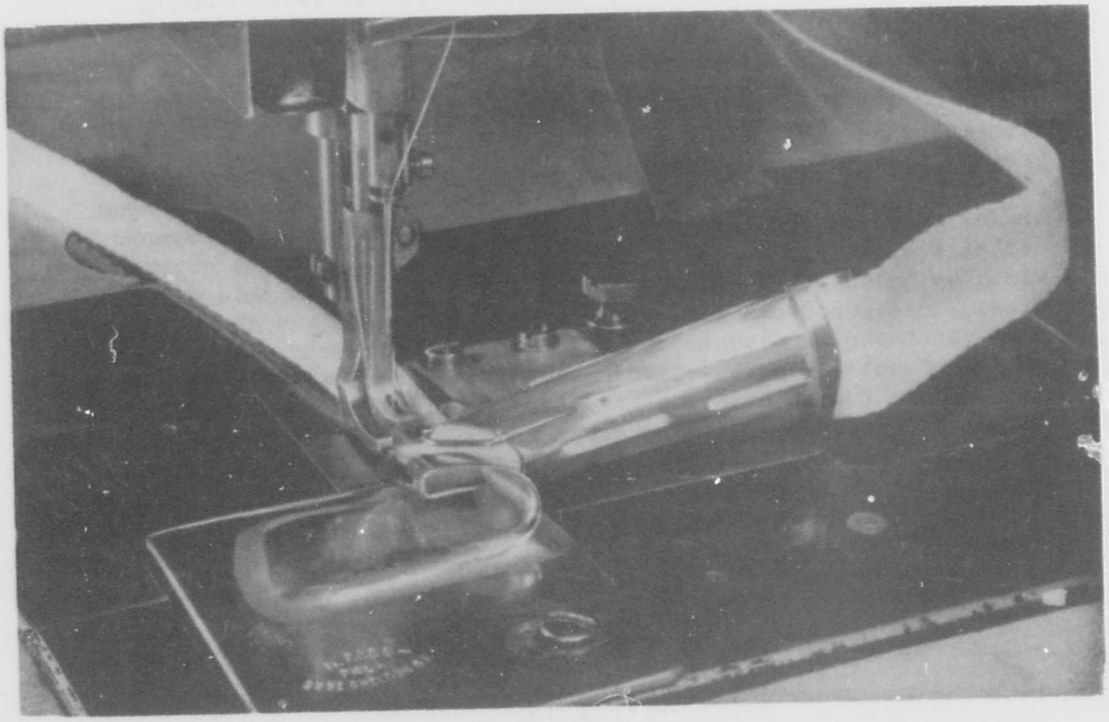

FIG. 11. SEWING ATTACHMENT FOR BINDING AND HEMMING CENTER CUTOUT (DETAILED VIEW)

of the number of blows required to produce failure and subsequently allowed to relax for 24 hours. It was considered that ten per cent represented a sufficient loading for this test inasmuch as at this point (1) most of the ultimate impact sag had occurred and (2) the amount of fiber rupture was not so great as to prevent a normal recovery from sag.

All laboratory tests of cover functionability were conducted at approximately 35 per cent relative humidity and 75°F.

Investigation of Fabrication Factors. The impact machine was first utilized to investigate the principles of cover fabrication. Variations of the following factors were studied, the specification material (18-ounce chafer duck) being used as the test fabric: center cutout pattern, location of hem lines, thread size, type of web bindings, and type of hem stitch.

Investigation of Fiber Types and Fabric Construction. After the design weak points had been eliminated it became possible to undertake a direct study of the influence of fabric construction on cover durability. Once fabrics featuring high breaking and tearing strength, and high and low extensibility had been evaluated, it became apparent that elongation or "give" is the decisive factor in controlling impact resistance. Furthermore, elongation is of primary importance in the yarns running across the cover width as all the impact failures occur in these yarns. (See Figures 2, 3, and 5).

The first method attempted to achieve better fabric elongation involved the use of fibers whose inherent stretch was greater than that of cotton. In investigating this approach, covers made of normally constructed nylon and high-tenacity rayon chafer fabrics were evaluated for impact resistance. The second method was limited to securing greater elongation in the cover width by enhancing the crimp in the yarns running in this direction. This procedure is logical since yarn crimp was found to be the most important constructional factor in determining the elongation of cotton ducks. The increase was accomplished by (1) so positioning the material during cover fabrication that the normally higher-crimped warp yarns are widthwise and (2) using a fabric in which the desired yarn crimp has been produced by control in the weaving operation.

Investigation of the Influence of Laundering on Cover Fit and Durability. Another phase of the investigation was concerned with laundry shrinkage which in field usage prevents proper remounting of the cover on the frame. The seriousness of this problem is indicated by a military analysis report(2) which states that "practically all" covers used required alteration to compensate for shrinkage.

The loss of size due to shrinkage was determined on covers laundered five times and fitted on a standard wooden frame. The influence of washing on durability was ascertained by comparing the impact resistance of covers laundered once with that of unlaundered covers of identical construction.

Service Studies. A preliminary service test was conducted to determine the effect of the new cover design and fabric on the functional aspects of comfort, durability, and ease in assembling the cot. Additional studies to be carried out in this connection include a limited production of the recommended fabrics and fabrication of covers using the redesigned pattern to determine their adaptability to large-scale manufacturing conditions. These covers would then be evaluated for performance in extensive field service tests.

V. RESULTS

Fabrication Studies

Improvement of Cover Durability. Failures at the center cutout section of the specification cover were eliminated by the following changes:

a. Relocation of the side hems by use of deeper folds so that the lines of hem stitching do not terminate at the sides of the center cutouts.

b. Adoption of a webbing which serves as a fabric support as well as a binding for the center cutout.

c. Modification of the inside curvature of the center cutout.

The extent of these changes may be seen in a comparison of the specification and redesigned pattern drawings shown in Figure 12 and the center cutout sections of finished covers shown in Figures 13 and 14. Test covers of the specification 18-ounce fabric, using both the original and redesigned patterns, were evaluated by the impact apparatus. When an eight-inch drop was used, the specification covers failed after an average of five blows, whereas the redesigned covers withstood an average of 117 blows. Figure 15 shows the specification cover after failure, and Figures 16 and 17 the redesigned cover. The shift in the location of impact failures from the center cutout section to the hem line and cover body is an indication that the weaknesses of the cover design were eliminated by the pattern changes. The redesigned pattern also permits a saving of approximately ten per cent in fabricating time.

The requirements of the above changes are detailed as follows:

a. Relocation of Hem Stitching. The additional depth of the side folds requires a base fabric 40 inches in width, in place of the specification $38\frac{1}{2}$-inch fabric. An entrance slit must be made by the cutting knife in order to follow the line of the new center cutout pattern as indicated in Figure 12a. To secure the flaps around this entrance cut during the hemming operation the addition of a webbing patch is necessary (Figures 12b and 14). An appropriate length of Type I, one-inch cotton webbing (as specified for binding the end cutouts) is suitable for this purpose*.

b. Substitution of Center Cutout Binding. Support of the base fabric requires a webbing whose load-elongation characteristics approximate those of the fabric filling yarns. On

*Since this patch does not contribute to the durability of the cover, a proper length of $1\frac{1}{2}$-inch adhesive tape (torn off after hemming) was found to be an adequate substitute for the stitched webbing. Adhesive tape is not recommended, however, because its subsequent removal exposes raw fabric edges.

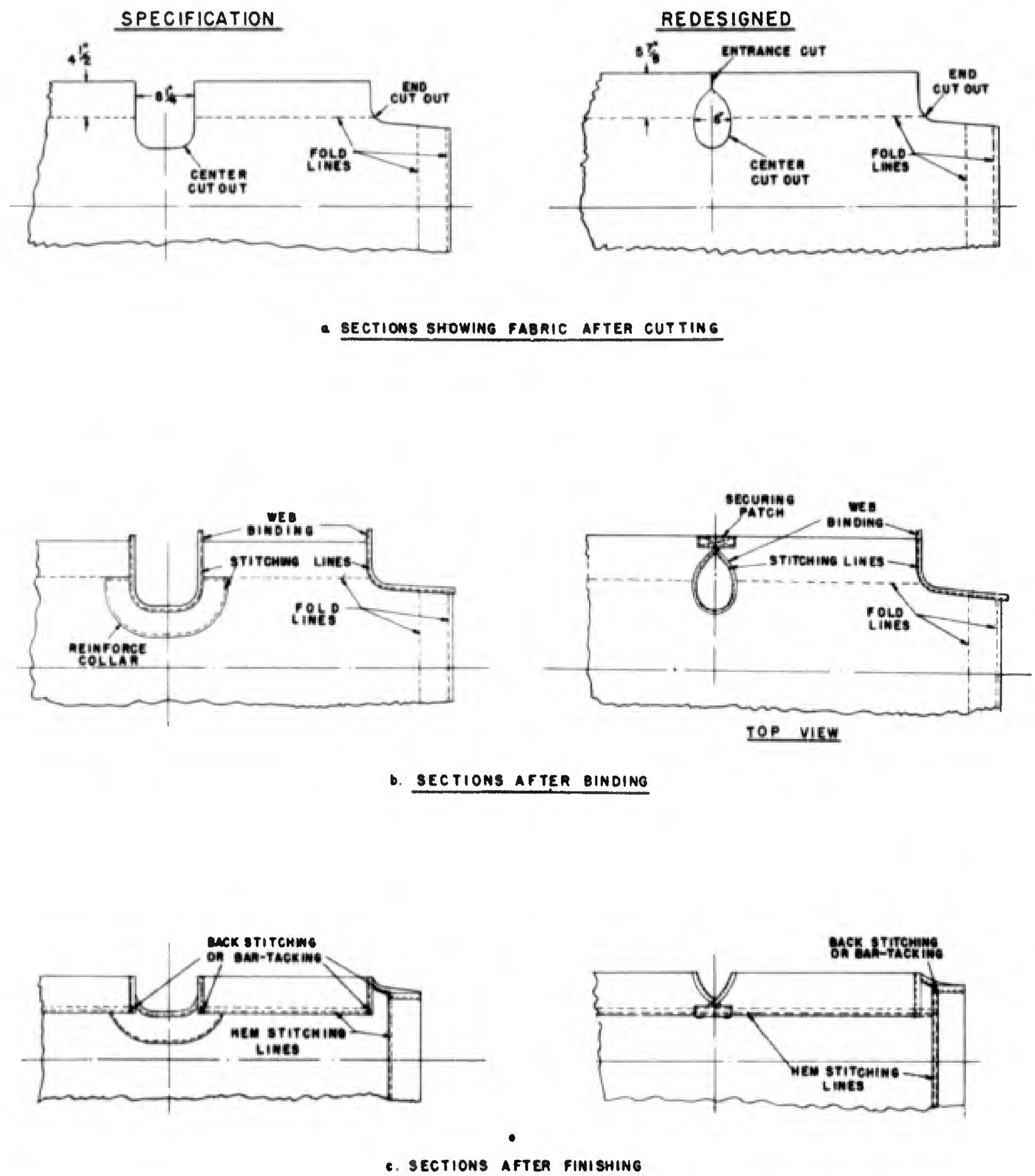

FIG. 12. PATTERN DRAWINGS FOR SPECIFICATION AND REDESIGNED COT COVERS.

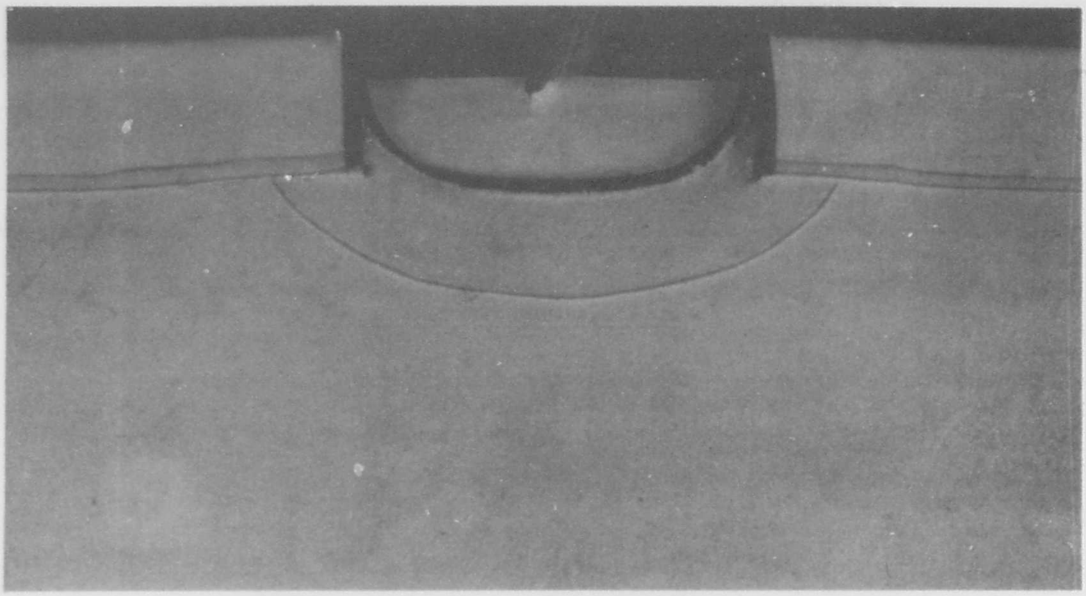

FIG. 13. SPECIFICATION CENTER CUTOUT (BOTTOM VIEW)

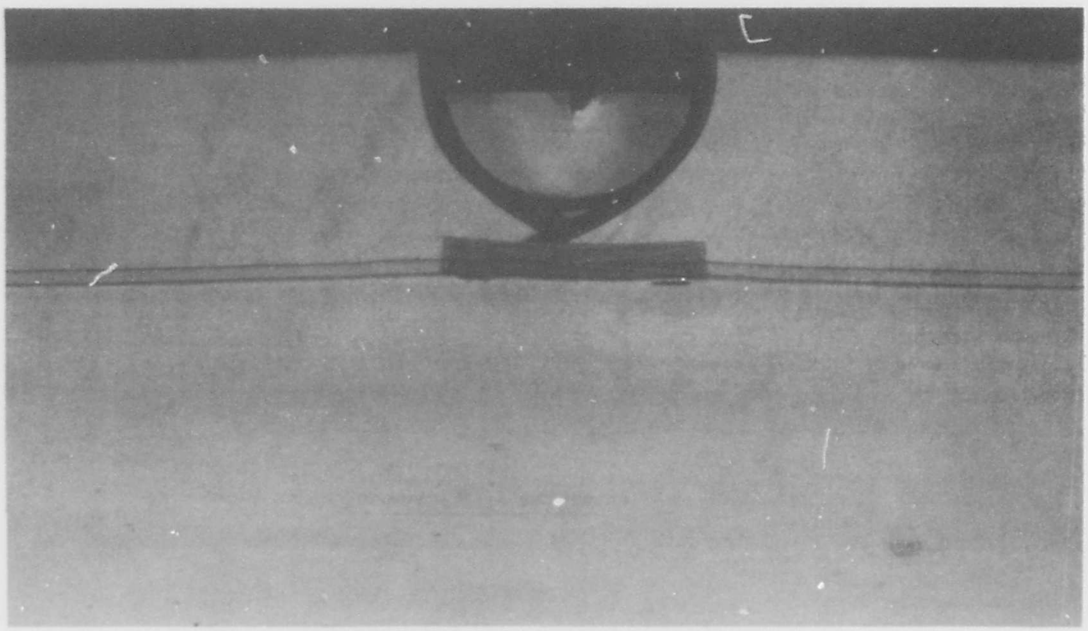

FIG. 14. REDESIGNED CENTER CUTOUT (BOTTOM VIEW)

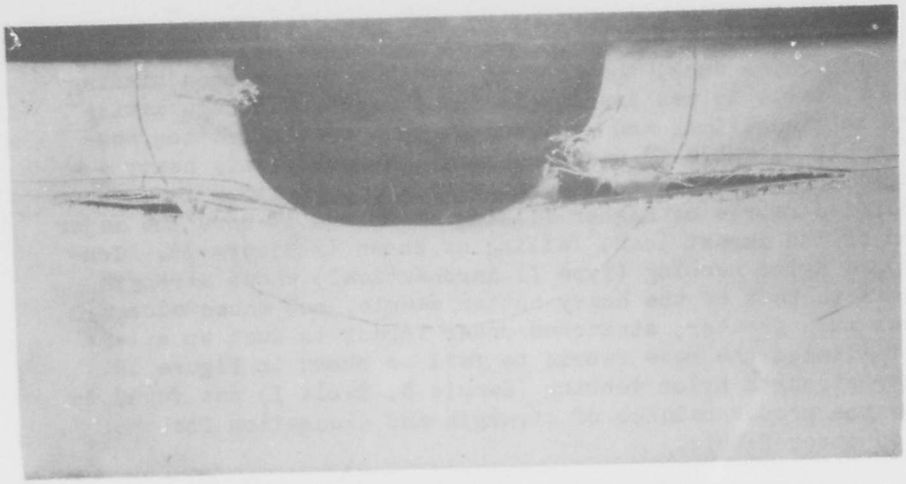

FIG. 15. LABORATORY IMPACT FAILURE (SPECIFICATION CENTER CUTOUT AND FABRIC)

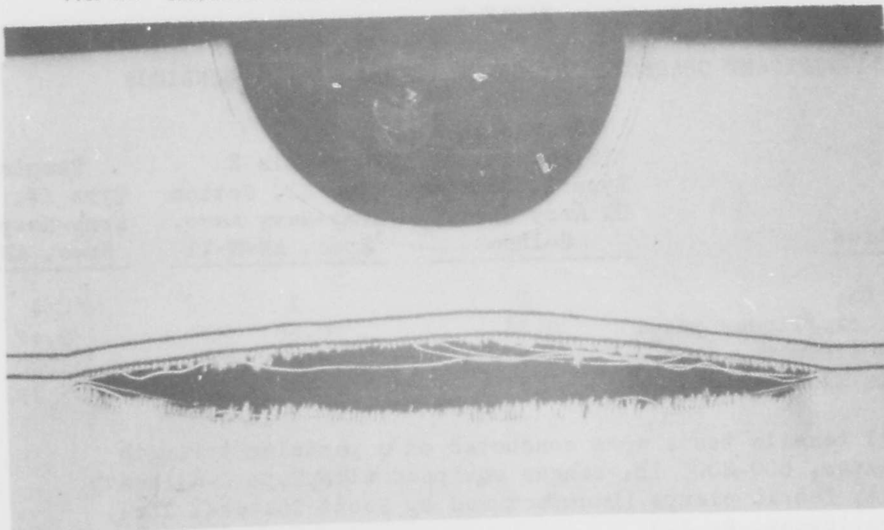

FIG. 16. LABORATORY IMPACT FAILURE (REDESIGNED CENTER CUTOUT, SPECIFICATION FABRIC)

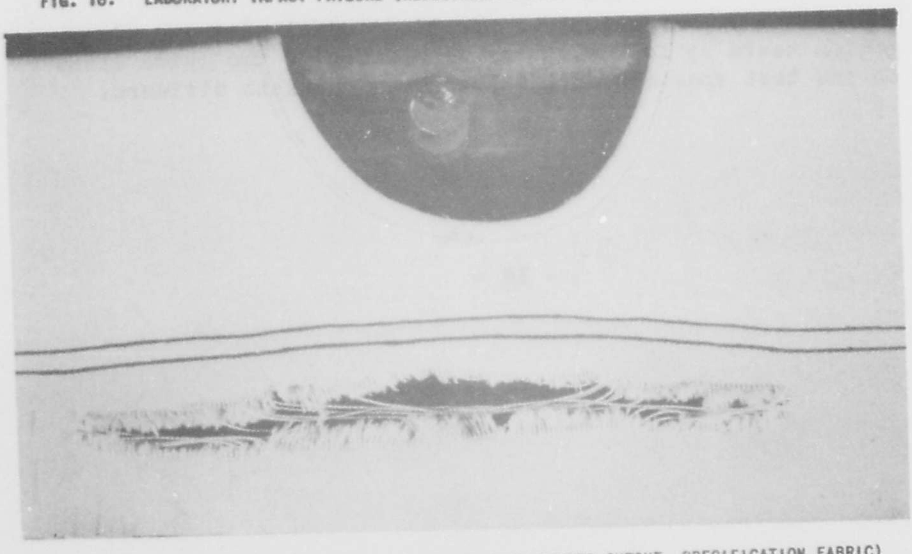

FIG. 17. LABORATORY IMPACT FA[illegible] (REDESIGNED CENTER CUTOUT, SPECIFICATION FABRIC)

standard 18-ounce duck, the present specification cotton binding (Sample 1, Table I) was inadequate in strength, although satisfactory in elongation, and replacement by a heavier cotton webbing (Sample 2, Table I) was necessary. However, this heavy webbing did not possess sufficient ultimate elongation for use on the modified fabric of higher filling crimp and it bore the major portion of the impact load, failing as shown in Figure 18. Conversely, a nylon webbing (Type II Aeronautical) whose strength was equal to that of the heavy cotton sample, but whose elongation was much greater, stretched under impact to such an extent that it allowed the base fabric to fail as shown in Figure 19. A higher-strength nylon webbing (Sample 3, Table I) was found to provide the proper balance of strength and elongation for the modified cover fabric.

TABLE I

SIGNIFICANT CHARACTERISTICS OF CENTER CUTOUT BINDINGS

Properties	Sample 1 (Spec. Item) Type I, Cotton US Army Spec. 6-185c	Sample 2 Type II, Cotton Army-Navy Aero. Spec. AN-W-21	Sample 3 Type IV, Nylon Army-Navy Aero. Spec. AN-T-83
Width, in.	1	1	1
Weight, oz./linear yd.	0.38	0.58	0.47
Tensile Strength, lb.[a]	200	716	1120
Ultimate Elongation %[b]	17	16	29

(a) All tensile tests were conducted on a pendulum strength tester, 500-2000 lb. ranges equipped with Type C-2, heavy duty fabric clamps (Manufactured by Scott Testers, Inc., Providence, R. I.)

(b) The amount of extension was measured in all ultimate elongation tests by following the separation of two guide lines on the test specimen with a pair of machinists dividers.

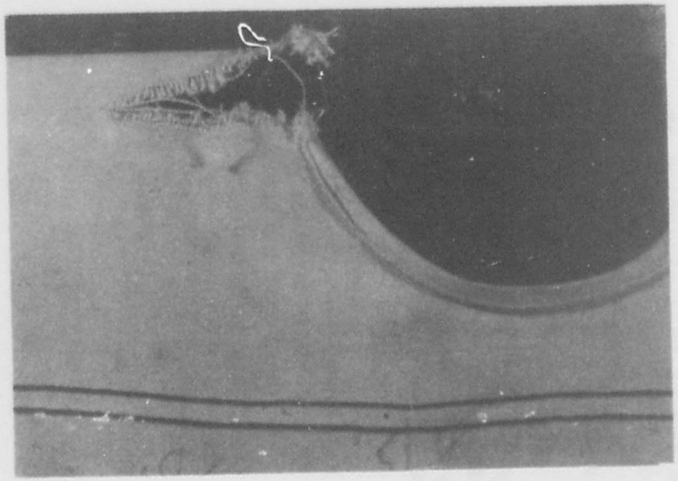

FIG. 18. LABORATORY IMPACT FAILURE
(REDESIGNED CENTER CUTOUT, TYPE II AERONAUTICAL COTTON BINDING)

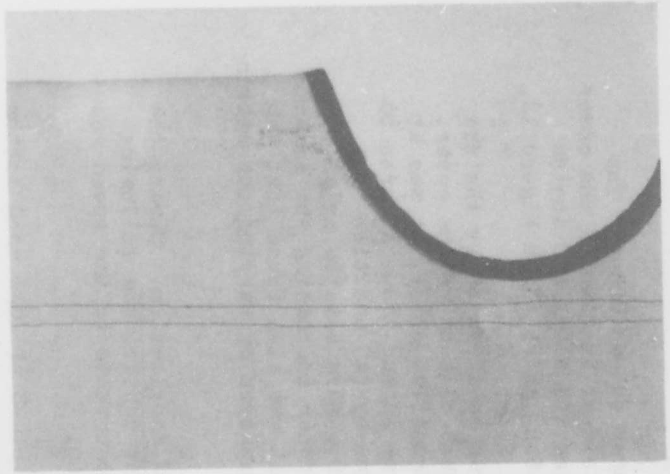

FIG. 19. LABORATORY IMPACT FAILURE
(REDESIGNED CENTER CUTOUT, TYPE II AERONAUTICAL NYLON BINDING)

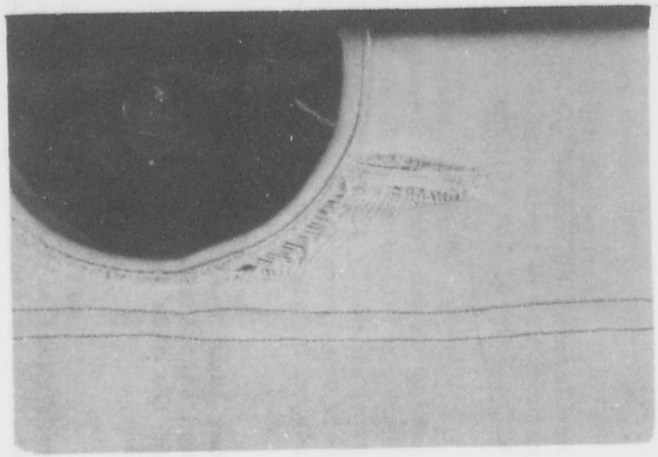

FIG. 20. LABORATORY IMPACT FAILURE
(SPECIFICATION CENTER CUTOUT SHAPE)

c. Modification of the Center Cutout Shape. The fabric failures bordering the center cutout section of the cover (Figure 20) were eliminated by changing the width and inside curvature of this element of the pattern, as shown in Figure 12.

The center cutout section was so improved by the new design that it was no longer the weakest element of the cover. When impact failure did occur in the modified cover, it was at or near the side hem stitching (Figures 16 and 17). Efforts to effect greater durability at this point by (a) addition of a third row of stitching, and (b) use of a more elastic nylon sewing thread were unsuccessful in further increasing the impact resistance of the redesigned cover. It was also found that hem strength could not be significantly improved by varying the stitch type.

Improvement in Efficiency of Fabrication. During the development of a more serviceable cover design, the following methods and materials were found to contribute to the speed and efficiency of the fabrication operation:

a. Thread. Use of 16/4 in place of 10/3 cord cotton sewing thread for all operations. Because of its good sewing characteristics and wide commercial usage, this thread was tried experimentally in the hemming and binding of several covers. It performed more satisfactorily than the specified thread and displayed no signs of failure in impact testing.

b. Hem Stitching. Elimination of back stitching or bar tacking at the ends of each row of side hem stitching. This hem stitching, if continued at least three inches beyond the end of the side fold is subsequently secured by the end folds (Figure 12c).

All other details of the specification cover design were found satisfactory, both from the standpoint of serviceability as measured in the laboratory and feasibility of manufacture under normal plant conditions.

Fabric Studies

Construction of a superior fabric must be based upon a knowledge of those fabric properties which are most conducive to cover durability. The characteristics considered most important in this respect were: ultimate elongation, elasticity, and breaking strength. These properties are most critical in the filling direction of the fabrics, since it was established that the filling yarns which normally run across the width of the cover bear the brunt of the impact load.

Effect of Filling Strength on Durability. In early selections of fabrics for cot covers, consideration was given only to high breaking and tearing strengths of the filling yarns. However, these criteria are invalidated by the outstanding durability of cotton chafer duck as compared to two heavier materials, one of which (No. 4 cotton duck) is noted for its high filling breaking strength and the other (axminster cotton duck) for its high filling tearing strength. It is notable that neither of these fabrics compares in impact durability to the chafer duck, as shown in Table II.

TABLE II

THE RELATION OF FILLING, TEARING AND BREAKING STRENGTH TO COVER IMPACT RESISTANCE

Properties	Specification Grey Cotton Chafer Duck (18-ounce)	No. 4 No. 4 Grey Cotton Duck (24-ounce)	Axminster Grey Cotton Duck (22-oz.)
Filling Breaking Strength (1-inch ravel strip, lb.)	215	290	230
Filling Impact Tearing Strength (inch-pounds/inch tear)	71	77	229
Cover Impact Durability 8-inch drop (No. blows sustained)	117	4	2

As shown in the above table, the chafer fabric is by far the most impact resistant despite its inferiority to the No. 4 duck in breaking strength (215 pounds versus 290 pounds) and to the axminster fabric in tearing strength (71 inch-pounds versus 229 inch-pounds). The specific properties which most strongly influence impact durability are not directly indicated by these results, but the figures do eliminate strength alone as a significant factor. That tearing strength is not important to cover impact resistance is further indicated by the fact that in the initial stages of fabric failure, only pure tensile breaking of the yarns occurs (Figure 21), after which the fabric splits with relative ease.

Effect of Fabric Elongation on Durability. The two factors which determine the ability of a textile material to resist an impact loading action are strength and elongation. Since it has been proved that strength alone is not the critical property, the next logical consideration is that of elongation.

a. Fiber Selection. Recognition of the importance of fabric elongation on cover durability led first to the consideratian of fiber types which combine the desired properties of high inherent elongation and required strength. Accordingly, a series of experimental chafer ducks made of spun nylon and filament high-tenacity viscose rayon, dyed olive drab, were evaluated as cover fabrics. Test results of these fabrics, together with those of the specification olive drab chafer duck (for reference) are given in Table III (page 22).

These figures show the outstanding durability of the nylon over the cotton and rayon fabrics. It appears that the superiority of the nylon is effected by its high strength as well as its retention of adequate elongation during repeated impact loadings. Practical considerations, however, militate against recommendation of nylon at this time because of its extensive use in higher priority items during periods of emergency and also because of its greater cost.

The rayon covers exhibited little capacity to recover from elongation after the first few impact blows, hence they showed only moderate improvement in durability over the considerably weaker and less extensible cotton covers. Furthermore, serious difficulties were encountered in fabricating the rayon into covers because of its smooth surface and limp body. Use of this material would entail special provisions in virtually all cutting and sewing operations in a standard canvas equipage shop.

The limitations of nylon and rayon forced a reconsideration of the more practical cotton fiber.

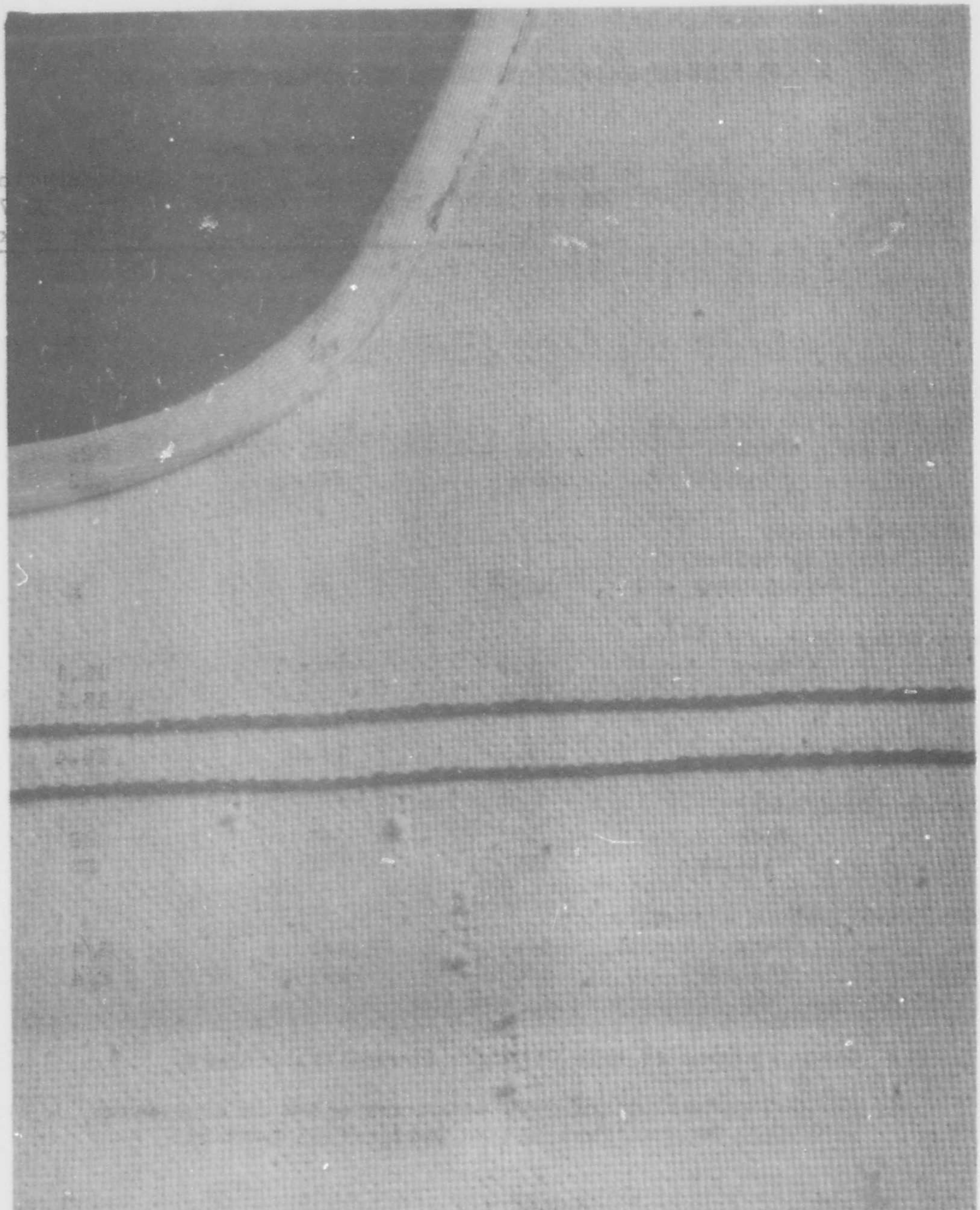

FIG. 21. INITIAL STAGE OF COVER IMPACT FAILURE (CENTER CUTOUT SECTION)

TABLE III

EVALUATION OF FABRICS OF DIFFERENT FIBER TYPES

Properties	Spun Nylon OD 7 Chafer Duck	Filament High-Tenacity, Viscose Rayon OD 7 Chafer Duck	Specification Cotton OD 7 Chafer Duck
Ultimate Elongation			
(Per cent) Warp	31	32	22
Filling	34	30	17
Breaking Strength			
(1 inch ravel strip, lb)			
Warp	355	280	225
Filling	325	248	213
Impact Durability			
(No. blows sustained)			
12-inch drop	500[a]	40	5
Yarn Crimp (Per cent)[b]			
Warp	13.9	10.9	18.1
Filling	15.0	9.4	13.1
Weight (oz/sq.yd)	19.0	12.2	18.4
Texture (ends/inch)			
Warp	17	37	26
Filling	20	31	23
Yarn Count (cotton system)			
Warp	6/4	4/1	8/4
Filling	8/4	4/1	8/4

(a) Tests stopped at this figure. Cover still intact.

(b) All determinations of yarn crimp conducted in accordance with ASTM General Test Method Designation D-39-39.

b. Yarn Crimp Control. Mechanical analysis of cover impact failures disclosed that the filling yarns must bear the brunt of the impact load (1) because they run the short dimension of the cover, hence are capable of less total elongation than those running the length of the cover, and (2) because they are normally woven with less crimp than the warp yarns. Recognition of the significance of yarn crimp as a factor in total fabric elongation suggested the possibility that a more durable cover might be produced by increasing the crimp of the yarns running in the cover width and decreasing the crimp of those running the cover length, thus shifting more of the impact load to the less extensible lengthwise yarns. Two methods of producing such a cover present themselves: (1) cutting the pattern from a fabric of sufficient width to accommodate the length of the cover, so that the relatively highly crimped warp yarns will run in the direction of the cover width (hereinafter referred to as "warp-width" covers); and (2) using a normal-width fabric in which the yarn crimp is controlled during manufacture

(1) Use of Extra Width Material in Fabricating "Warp-Width" Covers. Table IV presents a comparison of the results of tests conducted on covers made of No. 6 hard-texture grey duck fabricated both in the normal manner and with the warp running in the width direction. For reference purposes the characteristics of covers made of standard 18-ounce grey chafer duck are also shown.

The outstanding superiority of the "warp-width" covers over those fabricated of the same material in the normal manner clearly established the fact that significant improvement could be effected in the cover through a proper positioning of the high warp crimp and low filling crimp of the fabric (shown magnified in Figure 22). However, the limited manufacturing and finishing facilities available for 90-inch width duck made it advisable to consider the possibility of developing a standard-width (40-inch) fabric with warp and filling crimp controlled during manufacture.

TABLE IV

COMPARISON OF "WARP-WIDTH" COVERS WITH THOSE FABRICATED IN THE NORMAL MANNER

Properties	Grey Cotton No. 6 Duck (22-ounce) "Warp-Width" Fabrication	Grey Cotton No. 6 Duck (22-ounce) Normal Fabrication	Specification Grey Cotton Chafer Duck (18-ounce) Normal Fabrication
Fabric Width (inches)	90	40	38 1/2
Fabric Breaking Strength (1-inch ravel strip, lb)			
Warp	222	222	206
Filling	208	208	215
Fabric Yarn Crimp (per cent)			
Cover length direction	4.4 (fill.)	32.8 (warp)	24.4 (warp)
Cover width direction	32.8 (warp)	4.4 (fill.)	7.8 (fill.)
Fabric Ultimate Elongation (per cent)			
Cover length direction	9 (fill.)	33 (warp)	31 (warp)
Cover width direction	33 (warp)	9 (fill.)	13 (fill.)
Cover Impact Durability (No. blows sustained)			
8-inch drop	--	2	117
12-inch drop	500[a]	--	5

(a) Test stopped at this figure. Cover still intact.

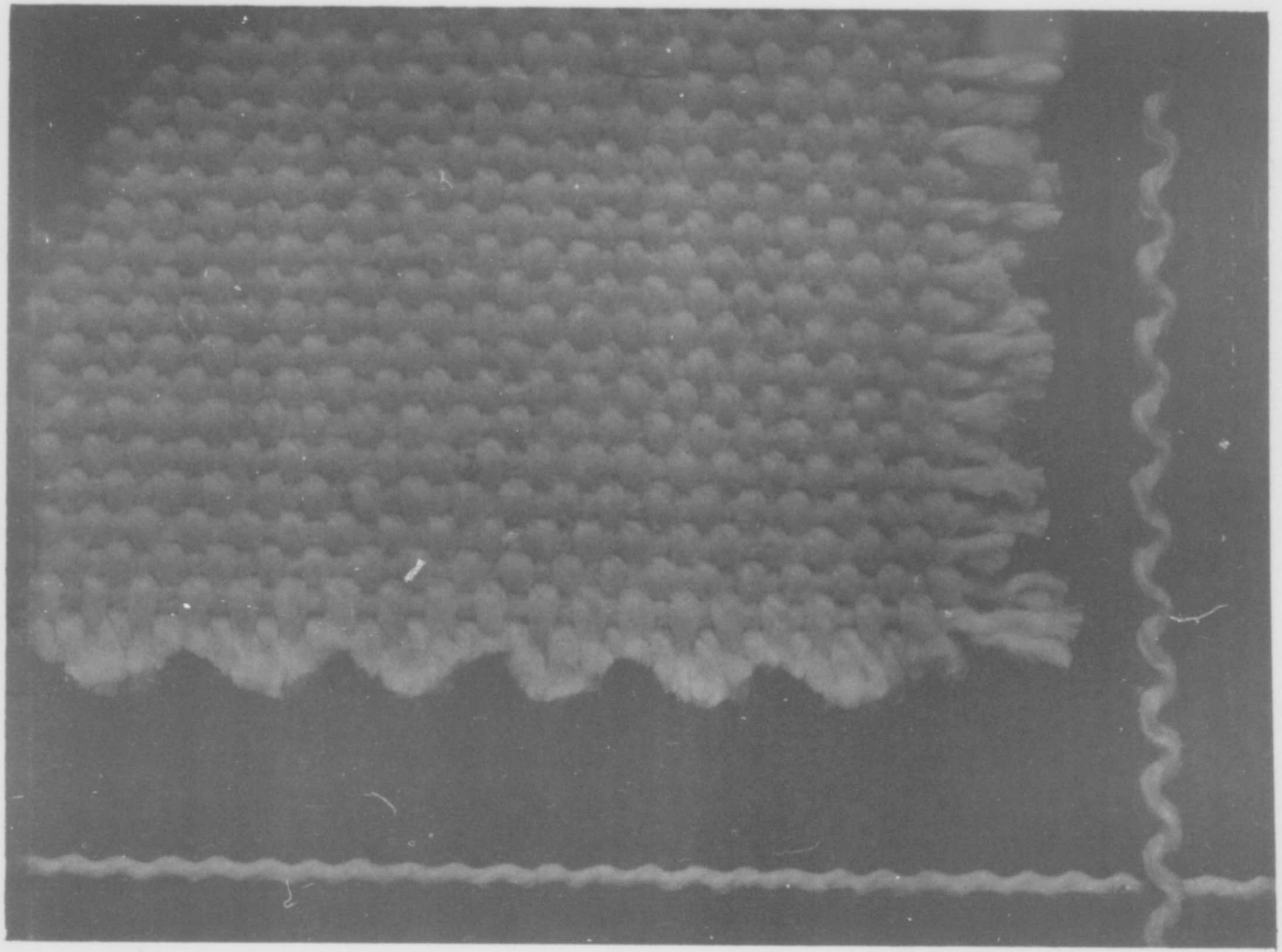

FIG. 22. MACROGRAPH OF NO. 6 DUCK AND YARNS (6X MAGNIFICATION, WARP VERTICAL)

(2) Regulation of Yarn Crimp in Manufacture. It was found possible to produce a fabric with increased filling crimp and decreased warp crimp by the same method used to manufacture "balanced" fabrics for rubber items, that is, by applying an extra tension to the warp yarns in the weaving operation*. Chafer duck was chosen as the experimental fabric since its "open" texture made it particularly amendable to such adjustment under normal manufacturing conditions. Based on the construction of the specification 18-ounce chafer duck, 200 yards of fabric were woven in which the warp-filling crimp ratio was progressively varied in four stages from 1:2.0 (approximately normal crimp control, Figure 23) to 1:0.7 (maximum crimp control, Figure 24). The laboratory test results of these four fabrics in addition to the standard chafer duck are given in Table V (page 29).

The progressive superiority of the controlled-crimp fabrics evidences the close connection between cover impact resistance and fabric elongation. From a functional standpoint only, the 4th-degree controlled sample is ideal but the rigid weaving conditions required in manufacturing this fabric make it impractical for large-scale production. On the other hand, the 3rd-degree controlled sample, which also shows a marked superiority over the standard, is adaptable to mass-production methods.

The improvement in the controlled samples is directly attributable to increased filling crimp and decreased warp crimp. It is notable that this greater impact resistance is obtained despite the fact that these fabrics are only slightly higher in breaking strength than the standard sample and actually lower in total (warp plus filling) elongation.

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*Stretching a "wetted-out" fabric, then drying while still under tension (as is done normally in finishing operations), is another possible method of adjusting crimp. However, the extra percentage of filling crimp gained in this manner is completely "loose" in the fabric and does not enhance the capacity of the material to absorb or recover from a loading action as would a corresponding amount of woven crimp. For this reason, cover impact resistance is not improved by finishing in spite of the normally favorable crimp balance created by this operation. Illustrative of this principle is the fact that the 18-ounce cotton chafer duck is identical in impact resistance both in the grey and dyed form (compare Table III and Table IV.)

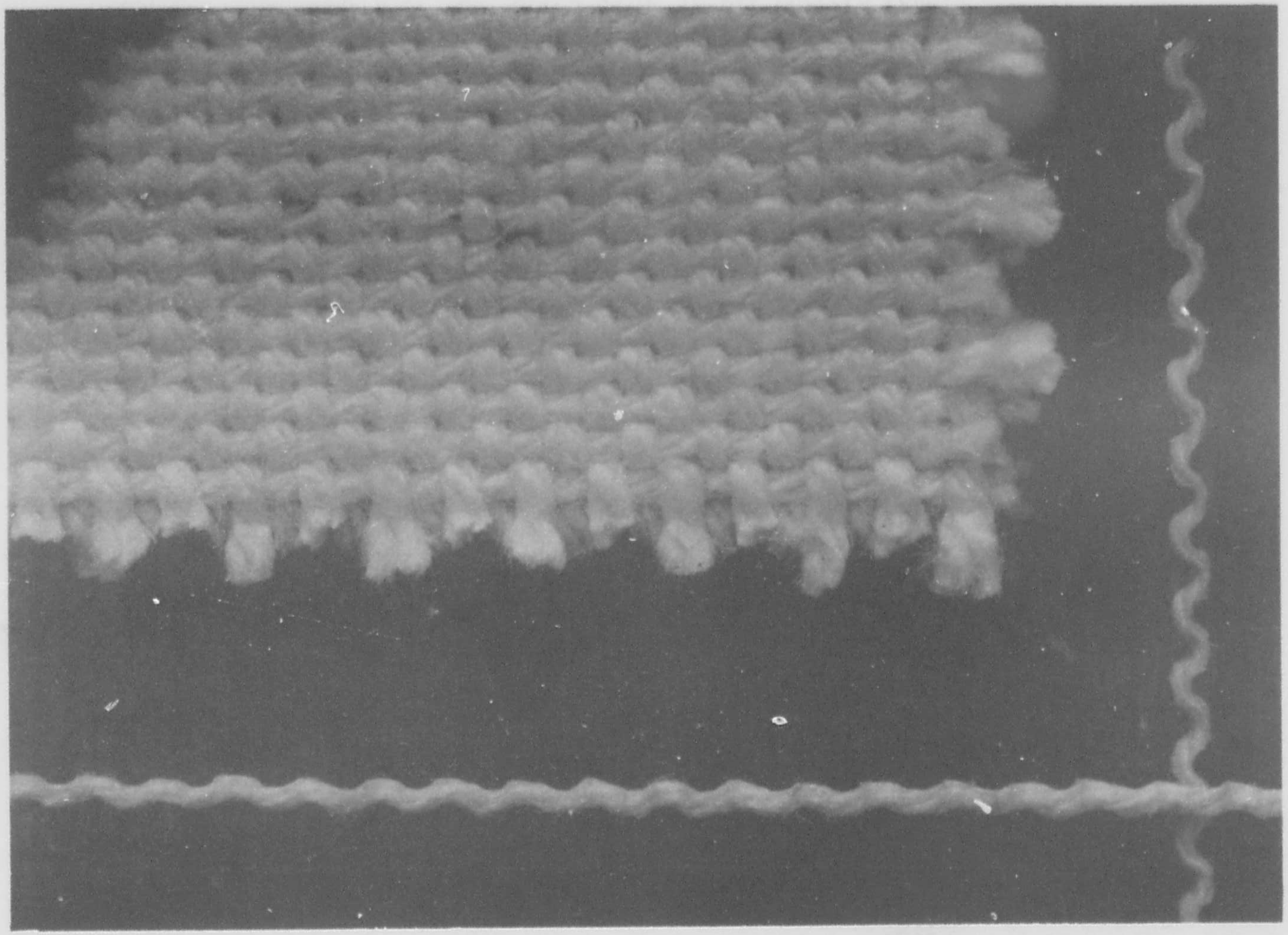

FIG. 23 MACROGRAPH OF NORMAL-CRIMP 18-OZ. CHAFFER FABRIC AND YARNS
(6X MAGNIFICATION, WARP VERTICAL)

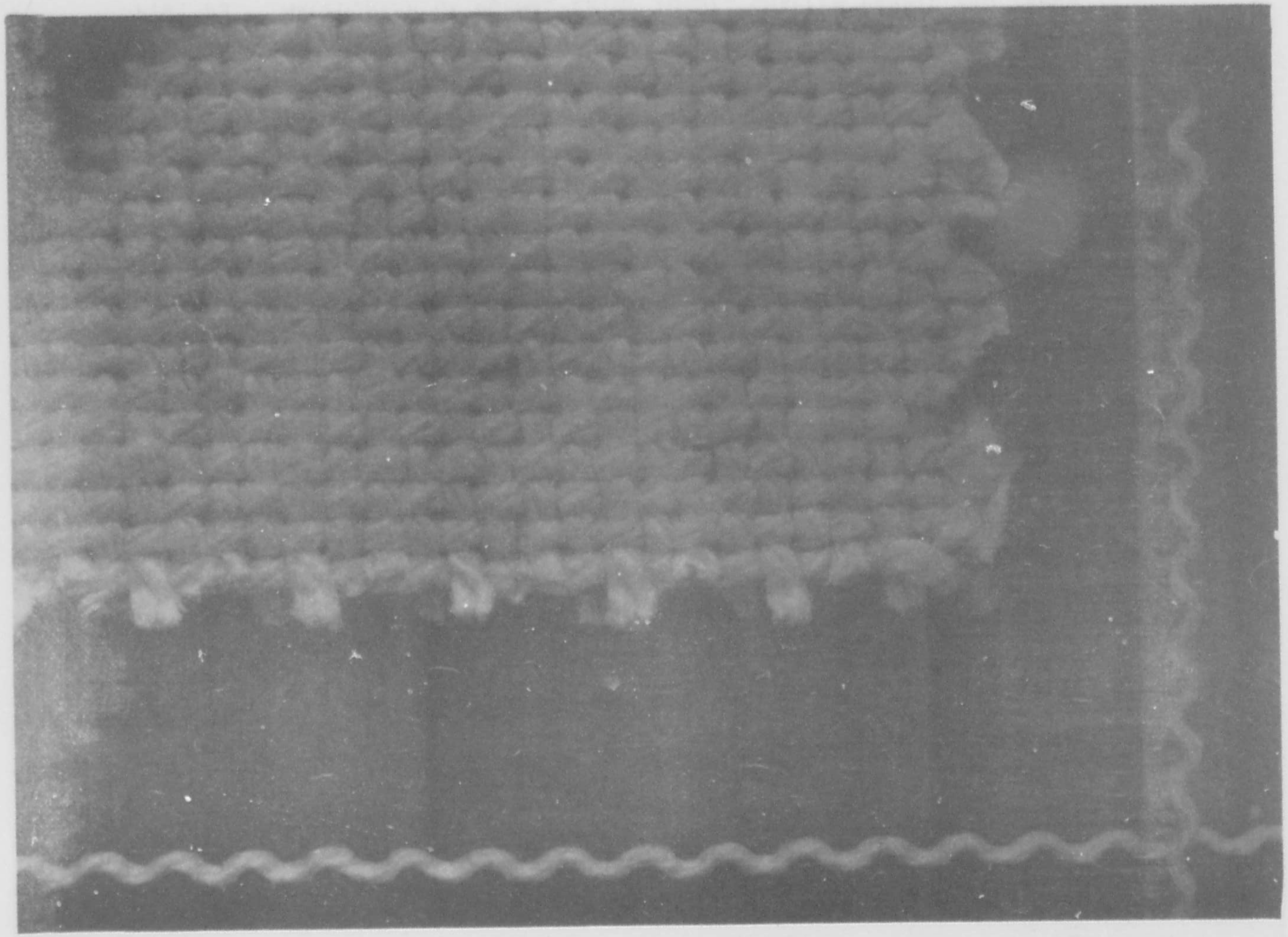

FIG. 24. MACROGRAPH OF CONTROLLED-CRIMP 18-OZ. CHAFFER FABRIC AND YARNS
(6X MAGNIFICATION, WARP VERTICAL)

TABLE V

COMPARISON OF 18-OUNCE CHAFER DUCK VARIED IN PERCENTAGE OF YARN CRIMP

Properties	Specification Grey Cotton Chafer Duck	Crimp-Controlled Grey Cotton Chafer Duck — Degrees of Crimp Control 1	2	3	4(max.)
Yarn Crimp (per cent)					
Warp	24.4	21.8	18.1	15.6	10.2
Filling	7.8	10.9	12.0	12.7	14.7
Ultimate Elongation (per cent)					
Warp	31	25	21	20	16
Filling	13	13	15	16	19
Impact Durability, 12-inch drop					
(No. blows sustained)	5	15	31	99	246
Range of values	4-6	6-25	18-50	68-120	180-317
Breaking Strength (1-inch ravel strip)					
Warp	206	210	224	221	233
Filling	215	245	244	238	250
Weight (oz/sq yd)	18.7	19.3	20.1	18.8	18.4
Texture (ends/inch)					
Warp	24	23	23	23	23
Filling	24	25	25	25	25
Yarn Number (cotton system)					
Warp	8/4	8/4	8/4	8/4	8/4
Filling	8/4	8/4	8/4	8/4	8/4

Effect of Fabric Sag on Utility and Comfort. Ability to support a weight, or conversly, resistance to sag under pressure, is the essential functional property of a cot cover. Regardless of its durability, the cover has little utility or comfort if it is (1) so extendable to allow the occupant to rest on the cross legs of the frame, or (2) so inelastic that it allows a permanent depression to be formed after a short period of service use.

Results of the sag tests conducted on covers of different types of fabrics are given in Table VI. The superior sag resistance of the "warp-width" cover is attributed to its low extensibility and high sag recovery. The nylon and rayon covers were considered less desirable because of their high extensibility under impact loading. In addition, the rayon cover retained as a permanent bulge a large portion of the sag produced by impact.

The sag properties of all the cotton chafer fabrics were satisfactory in all respects.

Laundering Studies

An investigation was undertaken to ascertain the exact influence of laundering on fit and durability of the cot cover. For this work a series of experimental covers made from fabrics most promising in impact resistance were tested after being subjected to laboratory-simulated cotton mobile launderings(4).

Fit on the Standard Cot Frame after Laundering. From the standpoint of utility, cot-cover shrinkage becomes significant if it prevents proper remounting on the frame. Some dimensional losses incurred through shrinkage are tolerable, since they are restored by the tensions applied in fitting the cover on the frame. Studies were undertaken to obtain a quantitative determination of the critical shrinkage, i.e., that which takes place beyond this point of recoverability. The procedure consisted of laundering the covers five times, then measuring the additional cloth required to maintain a satisfactory fit on the wooden folding frame. The necessary increments were obtained by letting out the side and end hems.

A series of grey and dyed fabrics of different fiber types tested in this manner indicated that, in general, the laundered

TABLE VI

SAG RESISTANCE OF SELECTED FABRICS
(Tested in Cover Form)

Sag properties	Maximum allowable*	Spec. Cover Pattern	Redesigned Cover Pattern				
		Spec. Grey cotton chafer duck	Grey Cotton No. 6 duck, "warp-width" fabrication	Controlled-crimp grey cotton chafer duck: 3rd degree of control	Controlled-crimp grey cotton chafer duck: 4th degree of control	OD 7 Spun nylon chafer duck	OD 7 High-tenacity filament viscose rayon chafer duck
Amount of Sag (depression of cover), inches							
Static load	3-3/4	3-1/8	2-7/8	3-1/8	3-1/8	3-5/8	3-5/8
Impact load	3-3/4	3-5/8	3-3/8**	3-5/8	3-3/4	4-3/8**	4-5/8
Recovery of Sag after impact load and 24 hr. relax.		Good	Excellent**	Good	Good	Excellent**	Fair

*Covers which sag beyond this point permit the occupant to rest on the cross legs of the frame in actual use.
**Measured after 500 blows on the laboratory impact tester.

covers when fitted on the frame regained a majority or all of their dimensions lost in shrinkage. As shown in Table VII, covers of grey cotton chafer duck, for example, normally shrunk approximately 6 per cent in laundering and recovered approximately 4.5 per cent in mounting, requiring only 1 to 2 per cent enlargements; the covers of rayon chafer duck lost as much as 13 per cent of their length, regained this entire amount and required no dimensional additions. On the other hand, the dyed 18-ounce cotton chafer duck (which is the specified material for cot covers) shrank so excessively that an increase in length of 5.3 per cent was required to permit remounting a cover on the frame. The high shrinkage of this fabric is a result of the relaxation (in laundering) of the warp tensions which have been applied in the finishing operation. It was practical to allow for the small unrecoverable shrinkages of the majority of the fabrics by slight enlargement of the original patterns but covers of the dyed cotton chafer duck made with the necessary 5.3 per cent linear extension were so large before laundering that they fitted very loosely on the standard wooden frame. (A 5.3 per cent increase represents an addition of 4 inches to the cover pattern). The apparent solution to the problem of using dyed cotton chafer fabrics is, therefore, in preshrinking the material so that only small adjustments in pattern size are necessary.

Cover Durability After Laundering. Because of a possible effect of laundering on the important property of impact resistance, covers were tested on the laboratory impact apparatus both before and after one laundering. Since all the covers were subject to some shrinkage, their fit on the test frame after laundering was generally tighter than before. (One exception to this rule was the rayon covers whose shrinkage was fully recovered in remounting.) It was considered valid to test the laundered covers with a mounted tension higher than that of the unlaundered because the shrinkage incurred in field usage normally results in a similarly tighter fit on the frame. The results obtained are shown in Table VIII (page 34).

TABLE VII

EFFECT OF FIVE LAUNDERINGS ON COVERS MADE OF VARIOUS FABRICS

Properties	Specification Cotton Chafer Duck Grey	Specification Cotton Chafer Duck OD 7	Crimp-controlled (3rd Degree) Cotton Chafer Duck (Grey)	Spun Nylon Chafer Duck (OD 7)	High-Tenacity Viscose Rayon Chafer Duck (OD 7)	No. 6 Cotton Duck (Grey) "Warp-Width" Fabrication
Total shrinkage (relaxed) per cent						
length	6.2	10.5	6.8	6.5	13.0	3.0 (filling-wise)
width	5.2	4.0	6.8	1.5	1.5	3.0 (warp-wise)
Shrinkage Recovery in mounted cover per cent						
length	4.9	5.2	4.8	4.5	13.0	3.0 (filling-wise)
width	3.4	4.0	4.9	1.5	1.5	3.0 (warp-wise)
Additional dimensions needed for proper fit per cent						
length	1.3	5.3	2.0	2.0	0.0	0.0 (filling-wise)
width	1.8	0.0	1.9	0.0	0.0	0.0 (warp-wise)

TABLE VIII

EFFECT OF ONE LAUNDERING ON COVER IMPACT DURABILITY

Covers	Impact Durability (12-inch Drop) (No. of Blows Sustained) Unlaundered	Laundered	Change After Laundering (Per Cent)
Specification Cotton Chafer Duck (Grey)	5	23	+360
Specification Cotton Chafer Duck (OD 7)	5	5	0
Crimp-Controlled (3rd Degree) Cotton Chafer Duck (Grey)	90	373	+310
Spun Nylon Chafer Duck (OD 7)	500[a]	500[a]	--
High-Tenacity Viscose Rayon Chafer Duck (OD 7)	40	33	-5
No. 6 Cotton Duck (Grey) "Warp-Width" Fabrication	500[a]	500[a]	--

(a) Test stopped at this figure. Covers still intact.

It is significant that all the grey laundered fabrics displayed greater impact resistance than did their unlaundered counterparts. (Possible exception is the "warp-width" covers which, like the nylon, were so durable both before and after laundering that it was not practicable to test them to the point of failure.) Although the grey covers fit more tightly on the frame after laundering due to warp and filling shrinkage of the fabric, their ultimate extensibility was unchanged. Consequently, the covers began to absorb the impact of each blow sooner because of their greater mounted tension, and allowed the load to be dissipated over a longer period of time, minimizing the shock effect. Thus the fabric was stressed to a lesser degree by each loading so that it was able to sustain a higher number of blows before exceeding its elastic limit.

On the other hand, no improvement in impact durability through laundering was noted in the dyed rayon and cotton covers. The laundered rayon covers did not have the advantage of greater mounted tensions because their width and length shrinkages were easily recovered in fitting on the frame. Although the dyed cotton covers required no extra tension in the width to be mounted on the frame, their length shrinkage was so excessive that an addition of two inches was necessary to permit even a tight fit in this direction. By thus extending the length of the cover, more warp crimp was introduced into the fabric with the result that more of the impact load was borne by the critical filling yarns.

Service Studies

As a provisionary check of their functionability, the experimental covers were subjected to small-scale service tests by laboratory personnel to secure information regarding comfort, durability, and ease of mounting on the frame.

The experimental pattern provided a somewhat more comfortable cover than did the specification design by minimizing the band of sag between the two center cutouts. The entire group of test covers displayed sufficient durability to withstand the total weight of four men sitting on the cot and the impact load of one man falling heavily on the cot. All covers were readily mounted and folded on the wooden frame*.

*In mounting tighter-fitting laundered covers on the frame, it was found advantageous to position the side-rail studs in the slot of each endstick until both endsticks are in position, then applying a vertical force to spread successively the side-rails and thus slide the studs along the slots into their proper holes.

Limited production of the most promising experimental fabrics and subsequent manufacture of these materials into covers of the new pattern design is now contemplated. In addition to determining the commercial feasibility of the changes in fabric and design, this work will furnish a series of experimental covers for a field-testing program. The results of these production and service tests will be used as a basis for revising the government specification for cot covers.

VI. SUMMARY AND CONCLUSIONS

Fabrication Studies. An engineering analysis of the weaknesses of the cover pattern indicated a need for the following changes:

1. Adoption of a nylon webbing for binding the center cutouts.
2. Modification of the center cutout shape.
3. Relocation of the side hems.

These changes, which can be made economically and without changing the normal fabricating procedure, were found to effect an increase in the impact resistance of the standard cover from 5 to 117 eight-inch blows as measured on the laboratory impact apparatus. It has also been found that the covers can be manufactured more efficiently by the use of 16/4 in place of the specified 10/3 cord sewing thread and by the adoption of an alternate method of stitching the side hems.

Fabric Studies. Development of covers of still greater impact resistance was accomplished by using the following fabrics which embody the constructional characteristics found to have the strongest influence on cover durability:

1. 18-ounce controlled-crimp chafer duck.
2. 19-ounce spun nylon chafer duck.
3. 21-ounce No. 6 duck, 90-inch width (so fabricated that the warp yarns run in the direction of the cover width - designated "warp-width").

Of the three materials, the controlled-crimp chafer duck appears to be the most practical from the standpoints of availability and production. Covers made of this fabric (in the modified design) are capable of withstanding 90 twelve-inch blows on the impact tester whereas similar covers of the specification material failed after 5 twelve-inch blows. They also display good sag resistance and ability to recover from sag. Both the nylon and "warp-width" covers are superior to covers made of the controlled-crimp duck in impact resistance, each displaying an ability to withstand more than 500 twelve-inch blows on the impact device. The nylon shows fair sag resistance and excellent recoverability from sag, while the "warp-width" covers are excellent in both respects. However, use of the synthetic fabric is restricted by virtue of its higher cost and limited availability in times of emergency, while the weaving and finishing difficulties associated with production of the 90-inch width duck limit the possibilities of the "warp-width" covers.

Laundering Studies. The laundering shrinkage exhibited by the covers made of dyed nylon and high-tenacity viscose rayon, and grey cotton duck is largely recovered by the normal tensions required in mounting the covers on the standard wooden cot frame. The small amount of shrinkage beyond this recoverable point can be compensated for by making minor allowances in the pattern size. However, the dyed cotton chafer duck (the material required by the present cot cover specification) is subject to such excessive warp shrinkage that pattern-size adjustment is impracticable. Preshrinking is therefore required to permit covers of this material to maintain an adequate fit on the frame both before and after laundering.

Impact tests of laundered covers indicate that their durability is enhanced rather than impaired by shrinkage.

Service Studies. All of the covers performed satisfactorily in limited service tests. Prior to adoption of the redesigned cover pattern and experimental fabrics, a small-scale production of the covers under normal plant conditions is recommended. These covers should then be subjected to extensive field trials.

ACKNOWLEDGMENTS

The help in development of the changes in pattern design and the careful fabrication of all the test covers by Mr. Frank Euler and Mrs. Margaret Purcell of the Philadelphia Quartermaster Depot Tent Shop are gratefully acknowledged.

Full appreciation is expressed to Mr. Norman Roberts of the laboratory staff for his extensive editorial assistance in the preparation of this report.

REFERENCES

1. Report of Col. Kruttschnitt, Post Quartermaster, Camp Haan, California, Nov. 1942, to the effect that with 75,000 covers in use, 11,500 were rendered unserviceable each month, of this number 2,500 must be replaced while the remaining 9,000 may be repaired. Col. Kruttschnitt further stated that cover failures are caused by tearing around the center cutout sections and he recommended the addition of a reinforcing collar around this section.

2. Basic Communication from the Military Analysis Section, Office of the Quartermaster General, dated 28 October 1946 stating that the most common type of breakdown in canvas cot covers was due to tears in the center cutout sections.

3. Report of Salvage in Western Pacific Area, Quartermaster Board Project S-163 which states that tears in the body area of the cover were the most frequent direct cause of salvage and that out of a sample of 517 salvaged covers examined, 371 were damaged by constructional failures, the remaining 146 by mildew and rot.

4. Mobile Laundry test with tumbler drying, Tentative Method No. 7450 (to be included in Federal Specification CCC-T-191) Textile Materials Engineering Laboratory, Philadelphia QM Depot.