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TEXTILE SERIES REPORT

NO. 124

QUARPEL APPLICATION AND TEST METHODS
FOR COTTON THREAD

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QUARTERMASTER RESEARCH & ENGINEERING CENTER
CLOTHING & ORGANIC MATERIALS DIVISION

JANUARY 1963

NATICK, MASSACHUSETTS

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<p>AD- Division 14 Accession No.</p> <p>Quartermaster Research & Engineering Center, Natick Mass. QUARPEL APPLICATION AND TEST METHODS FOR COTTON THREAD by Pauline P. Hall, Edward B. Frederick and Howard D. Corkum Jan 1963, 44 pp illus (Textile Series Report No. 124)</p> <p>The application of "QuarpeI" to cotton sewing thread and the resultant water repellency properties are described. A typical method of application is given. Test methods for determining repellency initially and after laundering have been developed and a new method of handling skeins in these tests has been devised. Data are presented which show the superiority of "QuarpeI"-treated thread over a commercial "durable" water-repellent compound in accelerated laundering tests.</p>	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> 1. Threads - Water repellency 2. Threads - Standards 3. Threads - Test methods 4. Cotton textiles - Impregnation 5. Water repellency 6. Finishes <ol style="list-style-type: none"> I. Hall, Pauline P. II. Frederick, Edward B. III. Corkum, Howard D. IV. Title V. Series 	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> 1. Threads - Water repellency 2. Threads - Standards 3. Threads - Test methods 4. Cotton textiles - Impregnation 5. Water repellency 6. Finishes <ol style="list-style-type: none"> I. Hall, Pauline P. II. Frederick, Edward B. III. Corkum, Howard D. IV. Title V. Series
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QUARTERMASTER RESEARCH & ENGINEERING CENTER

Natick, Massachusetts

CLOTHING & ORGANIC MATERIALS DIVISION

Textile Series
Report No. 124

QUARPEL APPLICATION AND TEST METHODS
FOR COTTON THREAD

Pauline P. Hall
Technologist

Edward B. Frederick
Technologist

Howard D. Corkum
Consultant

Fabric Engineering and Finishing Branch

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FOREWORD

The continuing search for improved items of combat clothing to protect the soldier against the natural elements has resulted in the development by personnel of this Command of a finish which is of a permanent nature. In contrast to the commercial compounds available classified as "durable", this finish can withstand many launderings without significantly reducing the protection initially afforded, and thus eliminates the need for retreating.

This finish, known as "Quarapel", was invented by Mr. Carlo DeMarco and Mr. Gil Dias who ably demonstrated its effectiveness on fabric. In order to provide the full protection of garments made of fabric treated with Quarapel, a study was made to determine if this finish could be applied to cotton sewing thread to provide seams equal in repellency to the Quarapel-treated fabric.

This report covers the application of Quarapel to cotton sewing thread and the development of test methods to assess its effectiveness.

S. J. KENNEDY
Director
Clothing & Organic Materials Division

APPROVED:

DALE H. SIELING, Ph.D.
Scientific Director

MERRILL L. TRIBE
Brigadier General, USA
Commanding

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ABSTRACT

The application of "Quarapel" to cotton sewing thread and the resultant water-repellency properties are described. A typical method of application is given. Test methods for determining repellency initially and after laundering have been developed and a new method of handling skeins in these tests has been devised. Data are presented which show the superiority of "Quarapel"-treated thread over a commercial "durable" water-repellent compound in accelerated laundering tests.

QUARPEL APPLICATION AND TEST METHODS FOR COTTON THREAD

1. Introduction

For many years the Quartermaster Corps has conducted research to develop improved items of water-resistant cloth for field use. Three basic approaches were followed. The first approach was to engineer superior fabric structures which would provide the tightness necessary to resist wind and rain. The second was the application of functional finishes to these fabrics to provide the optimum in water repellency of the fibers. The third approach was the development of water-resistant seam structures. Previous studies (1) had shown that the benefits offered by tight fabric structures and effective water-repellent finishes were not being fully realized because of leakage in the seams of garments. The primary cause of this leakage in woven cotton and cotton-blend fabrics appeared to be the thread.

All Quartermaster specifications for water-resistant items of clothing and lightweight textile equipage now require the use of water-repellent cotton sewing thread. The requirements for this thread, covered by Specification MIL-T-3530 for Treatments, Mildew and Water Repellent, for Thread and Twine, state that "The thread shall be treated with an approved water repellent compound such that the treated thread shall have a maximum dynamic absorption of 30 percent when tested as specified." At the time, only one compound was known to be capable of producing an all-round satisfactory water-repellent sewing thread. This was one of the quaternary ammonium salt types of compounds generally referred to commercially as "durable." This quaternary-treated sewing thread is now standard for all water-resistant items of clothing and lightweight textile equipage.

The adoption of a water-repellent thread for military items resulted only after extensive investigations (1) of many compounds in both the non-durable and the durable categories. These investigations showed that, while many of the compounds in both categories imparted an acceptable degree of water repellency to the thread, they also imparted other less desirable characteristics.

Of the many characteristics desired in sewing thread, one of the more important is that it shall function efficiently--with a minimum of breakage, skip stitching, slack and tight stitches, etc.--in the sewing machine during high-speed production. It was found that the non-durable finishes tended to impair sewability by making the thread stiff or giving it a tacky hand. Further, the accumulation of waxy substances at friction points in the sewing machine indicated that these finishes were being removed in sewing. It was not surprising, then, that the seams showed poor water resistance. Four durable-type compounds were also studied, and it was found that all except the one eventually approved adversely affected the sewing efficiency of the thread.

All sewing thread, with a few exceptions, is finished with a lubricating agent that imparts to it desirable surface properties and enables it to sew efficiently. Thread with high surface friction will develop high stresses when drawn through the tension discs and other thread-control devices on the sewing machine. When these stresses exceed the breaking strength of the thread, it will break and cause machine stoppage. The water-repellent-treated threads also require this added finish. However, some of the durable water-repellent compounds do not accept sufficient sewing finish to overcome the surface drag which they impart to the thread. Other durable repellents have a deleterious effect on the strength and elongation properties of the thread and because of this and their high surface friction they do not make acceptable sewing threads.

Late in 1959, the Quartermaster Research and Engineering Command announced (2) the development, by Mr. Carlo G. DeMarco and Mr. Gil M. Dias of the Textile Functional Finishes Laboratory, of a new water repellent finish for cotton textiles. It is a combination of a quaternary ammonium compound and a fluorocarbon which, when applied from the same bath, produces by synergistic action a water- and oil-repellent finish that has a high degree of durability to laundering. In fact, DeMarco and Dias (3) were able to show that a fabric so treated will, after many launderings, possess water repellency equal to that from the best commercial finishes before laundering. This finish is designated as "Quarpel", an abbreviated form of "Quartermaster repellent." See reference 6 and 7. This report covers an investigation of the application of this new finish to cotton sewing thread and of the suitability of Quarpel-treated thread for water-resistant items made of Quarpel-treated fabric.

2. Analysis of Seam Leakage

There is much disagreement in the trade about the mechanisms of seam leakage. Many people are convinced that leakage in seams occurs only through holes made by the sewing machine needle. Studies (4) indicate, however, that there are generally three contributing sources of leakage in almost any given seam. These are, not necessarily in order of their importance: a) seam type, b) needle holes, and c) wicking by the thread. Each will be discussed below.

a. Seam Type

Seam type (5) refers to the manner in which the fabric is folded in the seam. Leakage attributable to the seam type is that which goes through or between the layers of fabric in the seam. The fibers and yarns of wettable or non-water-repellent fabrics will conduct water through the folds of the seam by capillary action. Of course, wettable fabrics will, in addition, leak water through their structural interstices. Non-wetting surfaces will allow water to pass through the folds of the seam on the surface of the material. Stress on the seam structures, as

in bending, stretching, or crushing, during exposure to rain can cause the surface energy developed by a water-repellent fabric finish to be increased and thereby increase the tendency for leakage. The force or terminal velocity of the raindrops may also assist their penetration through the fabric structure.

Laboratory tests and rain-room studies have shown that the most resistant seam is the double-felled, double-stitched type LSc-2 (5). The so-called French seam, type LSr-2 (5), is almost as good but is not as consistent. In both of these seams, the fabric edges are turned to the inside to prevent water from seeping through. However, if the top fold of fabric in the LSr-2 seam is pulled too tightly in top stitching, the thread of the first stitching will be exposed and the needle holes will be enlarged.

b. Needle holes

Seam leakage may also occur through apertures made in a material by the penetration and withdrawal of the needle. These apertures are commonly referred to as needle holes or perforations. In coated textile fabrics and in leather and rubber materials, the cutting action of the needle certainly leaves a hole or perforation. In water-repellent-treated cotton fabrics, on the other hand, no holes are left unless the fabric has very poor seam efficiency. In fact, water repellents have been shown to improve the seam efficiency of fabrics by their lubricating and softening actions and thus to permit easier penetration of the needle through or between the fabric yarns.

The resiliency of the material being sewed controls the extent to which the apertures close after the needle is withdrawn. Here, too, the low surface energy developed by a water-repellent finish on the fabric plays a role because it causes the water drops to bridge the openings. This has been demonstrated by experiments which have shown that under certain static conditions there is no leakage through needle-holes-without-thread in a fabric that has good repellent characteristics. However, as noted above, when the fabric is stretched or flexed, as during the wearing of a garment, surface energy will be increased and leakage can occur.

c. Wicking by the thread

The leakage of water or other liquids through a seam by means of the thread is termed "wicking" and has been demonstrated in many ways. Ordinarily, as previously stated, threads are finished with a lubricant to enable them to perform satisfactorily in the production sewing room. Petroleum waxes in some form are the most common finishes now used.

These finishes are generally applied during the winding of the package upon which the thread will be shipped to the customer.

The methods of applying waxes or finishes to threads vary among manufacturers. Two methods used are: 1) running the thread between wax discs or cakes supported on a spindle, which allows the discs to revolve as the thread is pulled through them and the wax to be transferred to the thread surfaces by friction; and 2) drawing the thread over a cylinder or roll revolving in a hot wax melt. The finishing waxes vary in melting point from 120° to 180°F. In many instances, a combination of waxes with different melting points is used. During sewing, much of the wax is burned off the thread as needle heat is developed and as a result a sewn thread contains relatively small amounts of wax and therefore can absorb moisture.

Wetting agents used in dyeing and finishing, if not properly washed out, will hasten the wetting of the thread and increase the wicking of water through the seam structure. Thus, in order to obtain the full benefits of protection offered by a well-treated water-repellent fabric, it is necessary to treat the thread also so as to obtain the best possible degree of water repellency not only initially but after it is sewed into garments and subjected to repeated launderings. The Army has found it necessary to re-treat garments finished with the currently available commercial water-repellent compounds as early as after the first laundering or dry cleaning in order to restore the water repellency to the degree required for field wear. However, garments finished with Quarpel do not have to be re-treated even after many launderings. It therefore follows that the sewing thread must possess properties as nearly equal as possible to those of the Quarpel-treated fabrics to guard against leakage.

3. Procedures for Treating Cotton Thread with Quarpel

a. Skein method, preferred

The initial studies of applying the Quarpel finish to threads were carried out in the laboratory by means of the skein method. The objective was to determine the one best treatment with respect to: 1) initial water repellency, 2) water repellency after laundering, and 3) acceptable sewing quality. Various combinations of the quaternary salt and fluorocarbon compounds were applied to small skeins in varying amounts.

The Quarpel treatment which provided the optimum in the three characteristics desired was a combination of 6 percent quaternary compound and 8 percent fluorocarbon, based upon the weight of the thread being treated. These compounds were exhausted onto the thread. It was estimated by the clarity of the bath that at least 90 percent exhaustion was achieved.

Considering the solids content of both compounds and the almost complete exhaustion of the bath, it was also estimated that 3 percent of the quaternary compound and 2 percent of the fluorocarbon solids were deposited on the thread.

A cascade-type skein-dyeing machine was used and was found to be highly effective in attaining a uniform treatment. A typical procedure for applying Quarpel to threads in skein form, is essentially as follows:

Pretreatment:

Wet out the skeins at 180°F for approximately 10 minutes and then drain the liquor.

Rinse skeins at 90°F for 5 minutes and again drain the liquor. It is better to have the skeins slightly on the acid side, thus the rinse at 90°F should be slightly soured with a dilute solution of acetic acid.

Preparation of treating bath:

Dissolve the quaternary compound in 3 parts of water at 170° to 180°F and stir briskly until a good dispersion is attained.

Cool the dispersion to between 110° and 120°F with 2 to 3 parts of water.

Add the required amount of fluorocarbon directly to this stock solution of quaternary compound and stir well but not rapidly.

Treatment Proper:

Bring the water up to the required level in the treating machine, raise temperature to 90°F, stir in the treating solution, and run for 10 minutes.

Slowly raise the temperature of the bath to 160°F over a period of 30 minutes.

Slowly add a dilute solution of 1.5 percent sodium acetate (based on the weight of the thread) to the treating bath while elevating the bath temperature to 170°F. The pH of the bath should be at least 7 when 170°F is reached. Hold the temperature of the bath until the compounds are completely exhausted, then drain.

Rinse well for approximately 10 minutes at 130°F. Cool and extract.

Dry the skeins and cure at 250° to 275°F. Curing should be effected within 2 hours after the skeins are dry. It is good procedure to turn the skeins periodically during the drying and curing cycle, particularly if they are large.

b. Package method

After initial studies had proved that Quarpel could be satisfactorily applied to cotton sewing thread in skein form to provide high initial water repellency, durability to laundering, and good sewing characteristics, studies were run to determine if Quarpel could be applied in a package machine. Package treating has the advantage of being less expensive than skein treating because fewer operational steps are needed. Previous experience in treating thread with quaternary ammonium salt compounds by themselves had shown the package method to be unsuccessful, apparently because of the high rate of substantivity of the compound, which resulted in an extremely uneven treatment with the compound going on the outside of the package and on the inside at the spindle but not into the center. Small pilot plant treatments had shown similar results with Quarpel. Studies to determine whether a satisfactory package procedure can be worked out are being continued and are being carried out in cooperation with members of the thread industry.

c. Warp Method

A pilot plant study to determine the feasibility of applying Quarpel to cotton thread by the warp method was made by one member of the thread industry. Good initial repellency was obtained, but the durability did not prove to be as good as that obtained by the skein method.

4. Evaluation of Certain Physical Properties of Quarpel-treated Thread

a. Threads Tested

The initial investigations of Quarpel-treated threads were concerned with any changes in its physical properties that might be attributable to the finishing compound. Experience gained with the standard quaternary-compound water-repellent treatments on thread had shown that, if the application was properly made and the optimum curing times and temperatures were experimentally arrived at by the treating agency to suit their methods and equipment, there was no significant loss in the desirable properties of the thread. Therefore, in evaluating the Quarpel-treated thread, the standard or quaternary-compound-treated thread was used along with an untreated thread as a standard of reference.

The untreated control and the Quarpel-treated thread were from the same yarn and dye lot, but the standard treated thread was from a production lot, from the same manufacturer, that had been made to conform to the requirements of V-T-276b and MIL-T-3530A. The two sizes of thread chosen for the initial evaluation were 50, 3 ply and 70, 2 ply because these are the ones most commonly used. Generally, the 50, 3 ply is used as the needle and bobbin thread for all type 301 stitching and as the needle thread for all type 401 stitching. The 70, 2 ply is

used as the looper thread for all type 401 stitching and for various serging operations.

b. Stitching strength

Stitching strength tests were made to determine whether the slight differences in strength and elongation of the three threads (i.e., control, standard water-repellent-treated and Quarpel-treated) were of any practical importance in seams. Seams of 50,3 ply thread were made in samples of Cloth, Cotton, Oxford, 5.5-oz, Water Repellent, using seam type SSa-1 and stitch type 301, 12 stitches per inch, and a 1/2-inch seam allowance. The seams were tested for crosswise strength on a pendulum-type tester with a capacity of 150 pounds. The results are shown in Table I.

TABLE I

COMPARISON OF STITCHING STRENGTH OF THREE 50,3 PLY THREADS

<u>Thread</u>	<u>Strength of Stitching</u> (lb/inch)*
Control (untreated)	38
Standard water-repellent treated	39
Quarpel-treated	37

* Average of 10 tests

Only a slight difference in stitching strength was observed among the three threads tested. Thus, the effect the slight losses in loop strength and in elongation found in the Quarpel thread shown in Table I is negligible.

c. Sewing efficiency

Sewing tests of the three 50,3 ply threads were also made using a 2-needle high-speed laboratory sewing machine. Four layers of Cloth, Cotton, Sateen, 9-oz, Water Repellent, were sewn in an endless belt around the table of the machine. First the control and then the treated threads were used, with tension adjusted to produce first-quality stitching in stop-and-go cycles for a length of 20 yards. There were no improperly formed or skipped stitches and no thread breakage. The Quarpel-treated thread actually required less adjustment in changing from the control than the standard water-repellent thread, indicating a potentially better sewing quality for the Quarpel-treated thread than for the standard water-repellent thread.

In the tailor shop of the Clothing and Organic Materials Division of the Quartermaster Research & Engineering Command and in the Clothing Factory of the Defense Clothing & Textile Supply Center, limited production sewing tests were carried out in which the Quarpel-treated thread was used in the manufacture of experimental clothing made of a water-resistant fabric. No difference in sewing efficiency was noted between the Quarpel-treated thread and the standard water-repellent treated thread but again the Quarpel-treated thread required less adjustment.

d. Physical Properties

Single strand strength and elongation measurements were made by means of an incline plane tester with a capacity of 5 pounds and a distance between clamps of 10 inches. Elongation was graphically recorded simultaneously with the strength measurements. Loop-strength determinations were made on the same machine, using specimens consisting of two concentric loops of thread with one loop passed through the other and the ends of each loop placed in a clamp.

The data presented in Table II show very little difference in single strand breaking strength and elongation among the threads tested. In fact, the differences are small enough to fall within the expected normal range of variation for tests of this type. The loop strength of the Quarpel thread dropped almost 10 percent. This thread appeared slightly stiffer than either the control or the standard water-repellent thread. The yards per pound decreased for both the treated threads, which may be attributable to the add-on of finish. However, the tension under which the threads were wound onto the cones could have altered both the elongation and yards per pound to the small extent shown.

TABLE II
COMPARISON OF PHYSICAL PROPERTIES OF UNTREATED,
STANDARD AND QUARPEL THREADS

Thread	Tests			
	Single Strand		Loop Str. (lb)	Yards per Pound
	Elongation-%	Break. Str.(lb)		
<u>50,3 ply</u>				
Control	6.8	2.3	4.1	10,550
Standard WR	7.2	2.2	4.1	10,320
Quarpel	6.3	2.3	3.7	10,210
<u>70,2 ply</u>				
Control	5.2	1.4	-	15,770
Standard WR	5.7	1.2	-	15,210
Quarpel	5.1	1.2	-	15,620

5. Initial Water Repellency

The initial dynamic absorption tests, used to evaluate water repellency, were conducted on the three 50,3 ply threads, using Method 4500 of Specification CCC-T-191b (Appendix A). Two 5-gram skeins were taken from three cones each of the control, the standard water-repellent-treated, and the Quarpel-treated threads. The average results of six tests for each thread are given in Table III. These data show that the standard water-repellent and the Quarpel-treated threads possessed about the same degree of water repellency, which was about twice that of the untreated control as indicated by the percent absorption.

TABLE III

AVERAGE DYNAMIC ABSORPTION OF THREE 50,3 PLY THREADS (%)

Control (untreated)	64
Standard water-repellent	34
Quarpel	32

In the dynamic absorption test used above, the skeins are usually loosely folded into the jar of the tester. When they are withdrawn after the normal rotation cycle, each skein is so badly tangled that it is very difficult to straighten it out for wringing. The untangling operation results in broken plies, disturbed twist, and loss of absorbed water, and increases the time required to prepare the skein for wringing beyond the reasonable limits for preventing undue evaporation of water. Although the wringer rollers are loaded with a dead weight of 60 pounds, it is the condition of the skein when it is put through the roller that governs the pressure and the amount of water that will be squeezed out. Thick places in the skeins cause high pressure at those points and hold the rollers apart so that the thin places get little or no pressure. The width of the skein also influences the wringings, since the greater the area presented the lower the pressure per square inch. Thus the homogeneity of the skein as it is presented to the wringer, which is essential for reproducibility of results, is lacking when folded skeins are tested. The study of Quarpel-treated thread was therefore interrupted to investigate whether or not the method of handling or preparing skeins for dynamic absorption testing could be improved so as to prevent them from tangling and enable them to pass through the wringer rollers in a straight length and with some control over their width.

6. Development of a Reproducible Water Repellency Test Method

a. Cabling the skeins before testing

The handling of skeins of thread in water-absorbency and laundering

tests has always been a problem. Many methods of preventing tangling have been tried, such as inclosing the skeins in netting, cheese cloths, and similar materials, but none has been found sufficiently successful to warrant the extra work involved, nor was there any assurance that the materials used to encase the skeins were not unduly influencing the test results.

The Seams Engineering Laboratory at the Quartermaster Research and Engineering Command experimentally determined that twisting and folding of the skeins upon themselves, hereafter called cabling, could eliminate entanglement and consequently reduce the variability of results. Cabling involves rotating a skein around its long axis in the same direction as the final twist in the yarn and then folding the twisted skein back on itself, allowing the torque created by the twisting to back-twist the two legs of the folded skein around each other.

Use of Twist Tester for Cabling Skeins

To accomplish the cabling, a twist tester (Figure 1), adjustable to a gage of 25-1/2 inches between clamps and having a tension head, was modified by removing the thumb screws of the clamps and replacing them with a 1-1/2-inch bolt in the rotating clamp and a 3-inch bolt in the non-rotating clamp. Small rubber tubing was placed on the bolts to prevent damage to the thread and to facilitate the removal of the skein.

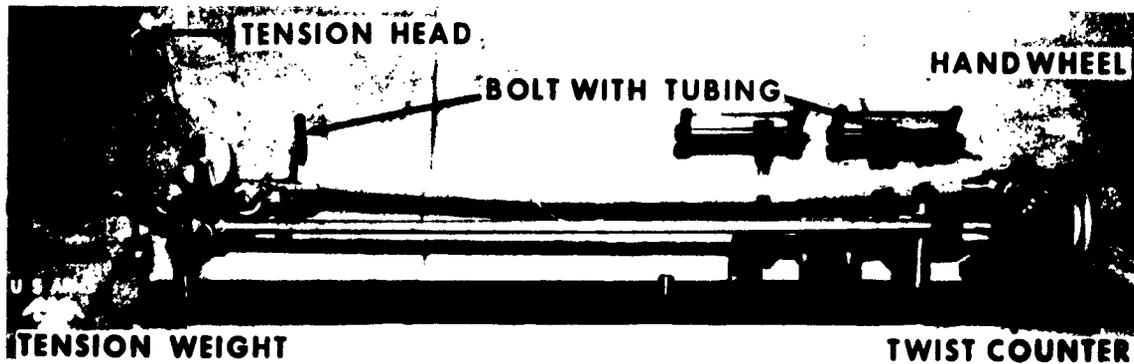


Figure 1. Skein on Twist Tester Before Twisting

In cabling, the skein is placed on the bolts and the hand wheel is rotated until the desired number of turns of twist (Figure 2) is inserted. The twist in the skein must be in the same direction as the final twist in the sewing thread because turning in the opposite direction would remove some of the thread twist. After twisting, the tensioning head is locked, one finger of the left hand is placed at the center of the twisted skein, and the loop is removed from the rotating head and carefully placed over the pin in the non-rotating head. The finger is then removed from the catenary thus formed and the skein is permitted to twist back on itself. The two loops are then removed from the pin and securely tied together.

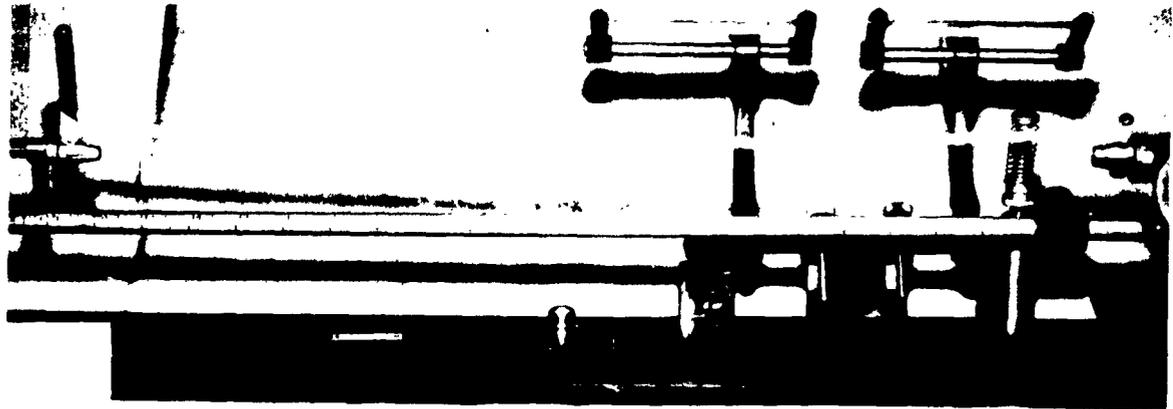
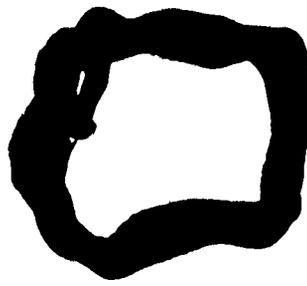


Figure 2. Skein on Twist Tester After Twisting

Comparison of Folded and Cabled Skeins

Figure 3 compares the condition of folded and cabled skeins before and after dynamic absorption tests. The skeins before testing are on the left side of the photograph and after testing on the right. In the tested cabled skein, the tie can be removed easily and the skein can be straightened out in a very short time with no entanglement and no visible disturbance of the thread twist or surface. The skein can then be laid out full length, with the sides placed close together, on a 2- by 30-inch blotter and wrung very uniformly. This method of cabling the skeins is most effective in the laundering of thread because the skein is not twisted tightly enough to impede the action of the detergent or to appreciably offset the effect of the mechanical laundering actions.



Before



After

a. **Folded**



Before



After

b. **Cabled**

Figure 3. Skeins Before and After Dynamic Absorption Tests

Determination of the Optimum Number of Turns of Twist

Limited experiments to determine the optimum number of turns of twist per cabled skein gave the results shown in Table IV.

TABLE IV

DYNAMIC ABSORPTION OF CABLED SKEINS WITH VARIOUS TURNS OF TWIST

<u>Number of Turns</u>	<u>Absorption</u>	
	<u>Avg. (3 Tests)</u>	<u>Range</u>
	(%)	(%)
Untwisted	42	38 - 47
5 turns	38	34 - 42
10 turns	42	36 - 44
20 turns	23	20 - 25
25 turns	17	16 - 18

The skeins cabled with 10 turns or less showed much higher average absorption and an absorption range of 8 or 9 percentage points; the tested skeins were tangled and appreciably matted and could not be straightened enough to be wrung uniformly. The skeins with 20 turns showed an average absorption of slightly over half that obtained with the skeins having 10 turns and an absorption range of 5 percentage points. The skeins with 25 turns showed an average absorption of only 17 percent and a range of 2 percentage points. Because of these data and the general conditions of the skeins with respect to tangling, 25 turns were selected as the optimum number to work with.

Variability of Folded Versus Cabled Skeins

In order to compare the relative variability of dynamic absorption data obtained by testing skeins loosely folded, as normally would be done in accordance with Method 4500 of Specification CCC-T-191b, and skeins cabled as described above, ten cones of Quarpel-treated thread were selected from a lot at random and two skeins were taken from each. One set of ten skeins was cabled on the twist tester before being subjected to the dynamic absorption test; the other ten skeins were "folded" and tested without twisting in accordance with the normal practice. Table V shows the individual skein values in terms of percent absorption, also the group average and the variance within the group.

TABLE V
 VARIABILITY OF DYNAMIC ABSORPTION RESULTS OF
 FOLDED AND CABLED SKEINS

Cone	Dynamic Absorption	
	Folded Skeins (%)	Cabled Skeins (%)
10	39.6	19.9
11	38.9	19.3
12	36.9	20.3
13	35.6	19.9
14	33.6	19.5
15	38.7	20.8
16	37.6	19.8
17	42.3	20.8
18	40.0	23.0
19	36.7	21.7
Group Average	38.0	20.5
Variance from average	6.06	1.28
Variance =		
	$F \text{ test} = \frac{6.06}{1.28} = 4.73$	
	$F_{.05} = 3.18$	

The average dynamic absorption (20.5%) for the cabled skeins as a group is shown to be only a little more than half that for the folded skeins (38%) and is considered to be the more realistic figure. It will be noted that the variance among the folded skeins (6.06) is far greater than that among the cabled skeins (1.28). The resulting F-test ratio of 4.73 is greater than the 5 percent level of significance for the F test (3.18). This means that there is a significant difference between the results of the two methods of skein handling. The principal reason for this difference, of course, is that the wringing of the two sets of skeins was not and could not be equally efficient. As pointed out above, the folded skeins always resulted in snarled, knotted masses of thread and each skein varied in shape, i.e., length, width, and thickness (Fig. 3,a Folded: after). This produced uneven roller pressure and, of course, inefficient wringing. The cabled skeins, on the contrary, after being untwisted for wringing, were unmussed (Fig. 3,b Cabled: after). They presented a uniform appearance and thickness throughout their length, which permitted the use of 2- by 30-inch blotters and led to efficient wringing and reproducible results. Furthermore, the ease of untwisting

the cabled skeins for wringing resulted in a significant savings of time over that required to untangle the loosely folded skeins.

On the basis of the foregoing, the skeins were twisted with 25 turns for all subsequent testing for dynamic absorption and laundering. The proposed method for dynamic absorption testing is described in full in Appendix B.

Additional Advantages of Cabled Skeins

Cabling can save much testing time because it permits up to three skeins to be run simultaneously in the dynamic absorption apparatus jar without affecting the average absorption or variance. Only one folded skein can be tumbled in a jar at a time. Two or more skeins when tumbled together become entangled within themselves and among each other and consequently are even more difficult to separate and untangle than skeins run singly. Comparative data, using cabled skeins from three cones of the same lot of Quarpel-treated thread, are presented in Table VI.

TABLE VI

DYNAMIC ABSORPTION OF CABLED SKEINS
TESTED ONE, TWO, OR THREE PER JAR

<u>Skeins per Jar per Test</u>	<u>Avg. (3 tests)</u> (%)	<u>Absorption</u>
		<u>Range</u> (%)
1	20.5	18.7 to 21.9
2	20.6	18.7 to 23.3
3	19.4	18.2 to 20.8

These data, while limited, agree closely with the data for cabled skeins in Table V and indicate that it is feasible to run three skeins simultaneously, for the range of 19.3 to 23.0 in Table V falls within the ranges shown above (18.2 to 23.3).

b. Desorption rate of Quarpel-treated thread following dynamic absorption tests

One of the causes of variability in the dynamic absorption of Quarpel-treated thread was thought to be the rate of desorption of the thread under the standard atmospheric conditions for textiles (70°F \pm 2, and 65% RH \pm 2%) during tests. In order to determine if the time between wringing and weighing the samples is critical to the test results, three

cones from one lot of Quarpel-treated thread were investigated. One skein was taken from each cone and cabled. These three skeins were tumbled simultaneously in one jar. The skeins were removed from the jar, untwisted, wrung one at a time, and then weighed at specified intervals. Each skein was loosely coiled on a separate filter paper throughout the weighing process and the timing was taken from the final wringing. The results, in terms of percent moisture retained (absorption) and rate of moisture loss from the original absorption (desorption) after various intervals, are given in Table VII and in Figure 4.

TABLE VII

DESORPTION RATE OF QUARPEL-TREATED THREAD

After Time (min)	Cone 1		Cone 2		Cone 3	
	Moisture Retained (%)	Rate of Desorption	Moisture Retained (%)	Rate of Desorption	Moisture Retained (%)	Rate of Desorption
2	21.8	--	20.4	--	17.9	--
5	21.3	2.7	19.9	2.4	17.3	3.4
10	20.4	6.9	18.9	7.4	16.5	7.8
30	16.9	22.5	16.0	21.6	13.4	25.1
60	13.2	39.5	12.7	38.7	9.7	45.8
120	7.5	65.6	7.0	65.6	6.1	65.9
180	4.3	80.3	3.6	82.4	3.0	83.2
240	2.4	89.4	1.9	90.7	1.6	91.1
300	1.2	94.4	0.9	95.6	0.8	95.5

These data show that the rate of desorption (% moisture loss) slowed down before equilibrium with the atmosphere was reached. Because the skeins were air dried in coiled form, less surface area was exposed and this may have hindered the desorption rate, especially near the equilibrium point.

These data further indicate that the length of time between wringing and weighing can be critical in borderline cases. The skein from Cone 1 dried for approximately 22 minutes before reaching the initial absorption of the skein for Cone 3 (17.9%). If acceptance or rejection of a lot of thread had been made on the basis of a retained moisture of 20 percent after one dynamic absorption measurement, Cone 1 would have been rejected if it had been weighed within 10 minutes after final wringing (20.4%) and Cone 2 would have been accepted if it had been weighed 5 minutes after final wringing (19.9%).

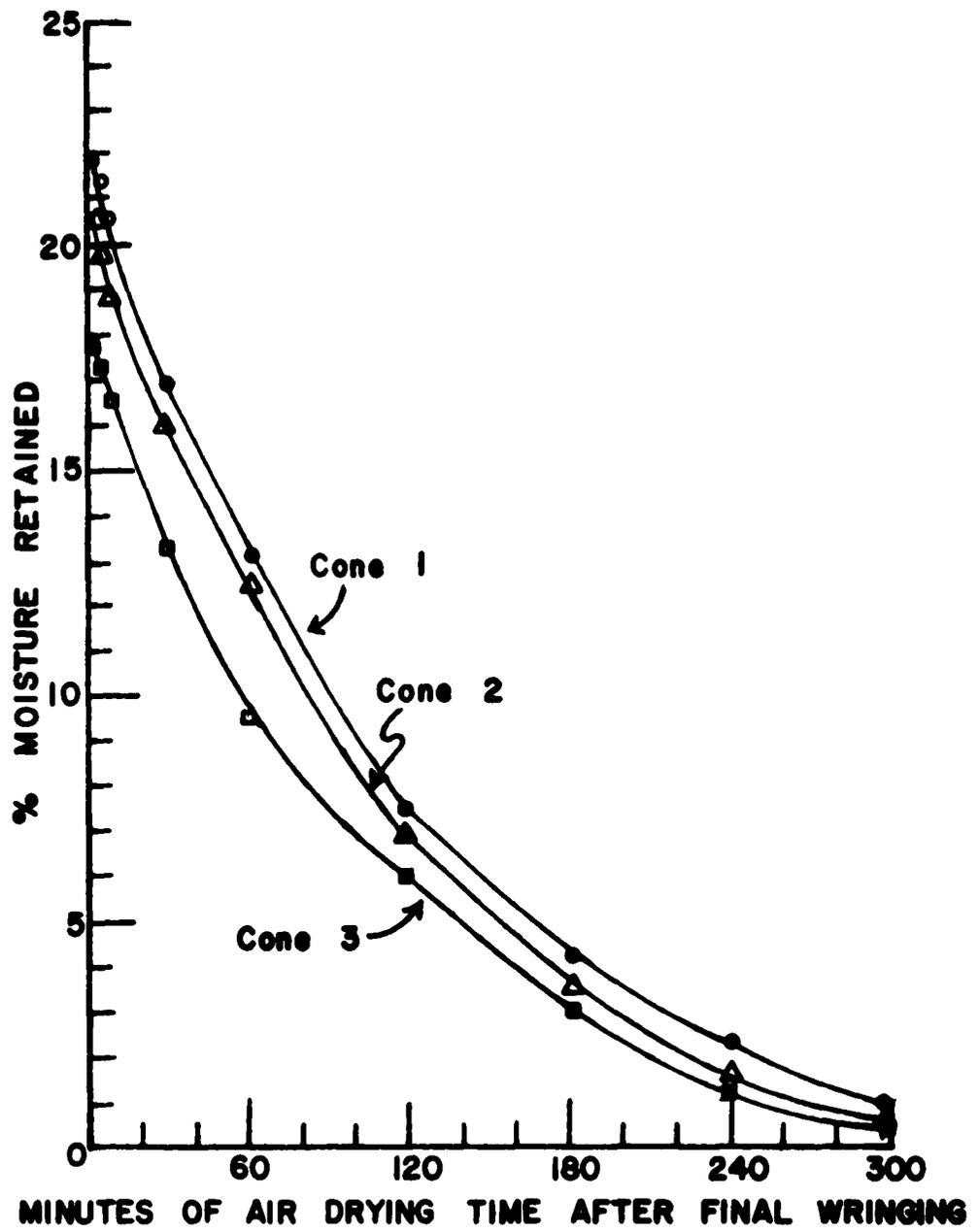


Figure 4. Desorption Rate of Quarpel-Treated Thread

c. Launder-Ometer versus tumbling jar for dynamic absorption tests

Because of the unavailability to the thread industry of the dynamic absorption equipment (tumbling jar) required by Method 4500 of CCC-T-191b, some preliminary investigations were made to determine the feasibility of using the Launder-Ometer as an alternative means of measuring the initial water repellency of Quarpel-treated thread. The Launder-Ometer is readily available to the industry and is simple to operate. Moreover, the time required to run skeins through a Launder-Ometer at capacity is only one-half that required to run the same number of skeins in the tumbling jar, even when 3 skeins are tumbled together.

A series of tests were made to compare the dynamic absorption of skeins run through a tumble jar and of those run through a Launder-Ometer. The values obtained by the two methods did not compare well. The amount of mechanical action in the tumbling jar (6-liter) was apparently far greater than that in the small jars (1 pint each) of the Launder-Ometer. Consequently, additional tests were run differing in water level, number of rubber balls, and length of time cycles. The conditions in the Launder-Ometer which appeared to give results most similar to those of the tumbling jars were found to be when:

1. The skeins were prepared in a cabled form, as previously discussed.
2. Each pint jar was filled with 100 cc of water and 20 rubber balls.
3. Each cycle was run for 30 minutes at 90°F.

Appendix C outlines the tentative methods for dynamic absorption tests using the Launder-Ometer.

Table VIII compares the water repellency of three lots of Quarpel-treated 50, 3 ply cotton thread as determined by the tumbling jar method (Method 4500) and by the Launder-Ometer method modified as described above. Each lot of thread was taken from a different production source (X, Y, Z) and three cones (1, 2, 3) were randomly selected from each lot. The data given are of a preliminary nature only.

TABLE VIII

**DYNAMIC ABSORPTION OF QUARPEL-TREATED THREAD
AS DETERMINED BY TUMBLE JAR AND LAUNDER-OMETER**

	<u>Tumbling Jar</u> (%)	<u>Launder-Ometer</u> (%)
<u>Lot X</u>		
Cone 1	13.6	11.8
" 2	14.2	10.5
" 3	<u>14.7</u>	<u>11.3</u>
Average	14.2	11.2
<u>Lot Y</u>		
Cone 1	27.0	30.4
" 2	39.5	26.6
" 3	<u>32.1</u>	<u>31.5</u>
Average	32.9	29.5
<u>Lot Z</u>		
Cone 1	15.5	14.4
" 2	15.0	11.1
" 3	<u>18.2</u>	<u>14.7</u>
Average	16.2	13.4

The Launder-Ometer method ranked the lot averages in the same order as the tumbling jar method. (Lots X and Z represent good treatments; Lot Y is only fair) The rates of difference between the threads were just about the same. These results, therefore, definitely indicate that the Launder-Ometer method as proposed is fairly reproducible and hence can be used in place of the tumbling jar method for determining the dynamic absorbency of water-repellent-treated threads, not only within a given lot but from different contractors. Additional studies are planned to determine the reproducibility of the Launder-Ometer method within one laboratory and among different laboratories.

d. Mechanical action of rubber balls versus steel balls

In order to determine if a different mechanical action would be obtained by using steel instead of rubber balls in the Launder-Ometer, tests were made using 20 steel balls per jar and 20 rubber balls per jar. Duplicate samples of Quarpel-treated threads from Cones 1 of Lots X, Y, and Z were tested both by the tumbling jar method and by the Launder-Ometer. The average results are given in Table IX:

TABLE IX

COMPARATIVE DYNAMIC ABSORPTION OF QUARPEL-TREATED THREAD USING STEEL OR RUBBER BALLS

	<u>Absorption</u> (%)
Tumbling jar method	18.7
Launder-Ometer method	
20 <u>steel</u> balls/jar	14.4
20 <u>rubber</u> balls/jar	18.9

During the cycles it was observed that the steel balls tended to roll along the surfaces of the rotating Launder-Ometer jars, with the result that the thread was in relatively little contact with them. The rubber balls, on the other hand, tended to bounce freely around the sides of the jars and to cause great agitation of the thread. The data also indicate that the steel balls produced less mechanical action than the rubber balls, since the absorption of the thread tested with the steel balls was 4.5 percentage points less than that tested with the rubber balls. The results obtained with the Launder-Ometer and rubber balls were almost identical to those obtained by the tumble jar method, indicating fairly good reproducibility. On this basis, it was considered that the use of the rubber balls would be advantageous and therefore they were used in all subsequent testing.

7. Launderability of Quarpel-Treated Thread

a. Laundering method used

DeMarco, et al (2) had shown that the water absorption properties of a fabric treated with Quarpel is practically as high after 15 launderings as a similar fabric treated with any of the well-known commercial durable finishes is before any laundering. Thus, it was considered important to determine whether or not Quarpel-treated thread is similarly durable to repeated launderings.

The first step was to determine whether a laboratory laundering method could be evolved which would enable the water repellency of Quarpel-treated threads to be evaluated after repeated launderings. An effort was made to simulate as nearly as possible the Army mobile laundering procedure for fabrics, but using more or less standard laboratory equipment instead of the wash wheel. The Launder-Ometer, with rubber balls, was chosen as the most suitable laboratory equipment because it was simple to operate and available to the thread industry. The following conditions of laundering were decided upon after some preliminary study and experimentation:

Specimens - 5 grams (± 0.5 gm) cabled skeins

Containers - Pint-size glass jars

Liquor - 1 percent sodium sulfonate salt of oleyl methyl tauride in
100 cc soft water

Temperature - 160°F (71°C)

Auxiliary Devices - 20 standard 3/8-inch rubber balls for added
mechanical action

Running time - 45 minutes

Rinse - running water starting at approximately 120°F and continuing
until all the detergent is rinsed away

Drying - air-circulating oven at 220° to 250°F (105° to 120°C)

Both the temperature (160°F) and the amount of the detergent (1%) recommended are higher than that specified for the mobile laundering of a fabric. This difference was considered necessary to insure the removal of the lubricating wax finish that is used to promote the sewing efficiency of thread and that might bias the absorbency results if not removed. Appendix D contains the proposed laundering procedure.

b. The effect of repetitive laundering cycles

Exploratory studies were conducted to determine if the thread could withstand the 15 launderings required for Quarpel-treated fabrics. It was found that after 12 consecutive launderings most of the threads began to disintegrate, therefore the skeins were laundered a maximum of 12 times, except for one lot which was laundered only 11 times. After each laundering cycle, in which the skeins were washed, rinsed, dried, reweighed, and allowed to reach equilibrium with standard conditions for textiles, they were tested for dynamic absorption. The results are shown in Table X and are plotted in Figure 5.

TABLE X

DYNAMIC ABSORPTION OF QUARPEL-TREATED THREADS BEFORE AND
AFTER 12 CYCLES OF LAUNDERING

		Average Absorption (3 determinations)			
		Thread D	Thread C	Thread B	Thread O
		(%)	(%)	(%)	(%)
Before laundering		9	15	13	13
After 1 laundering cycle		59	26	20	33
After 2 cycles		76	32	25	19
"	3	79	31	25	14
"	4	88	29	18	16
"	5	81	33	25	25
"	6	86	32	31	35
"	7	93	37	37	36
"	8	91	35	32	42
"	9	89	42	38	45
"	10	96	50	45	53
"	11	98	54	53	56
"	12	108	58	55	--

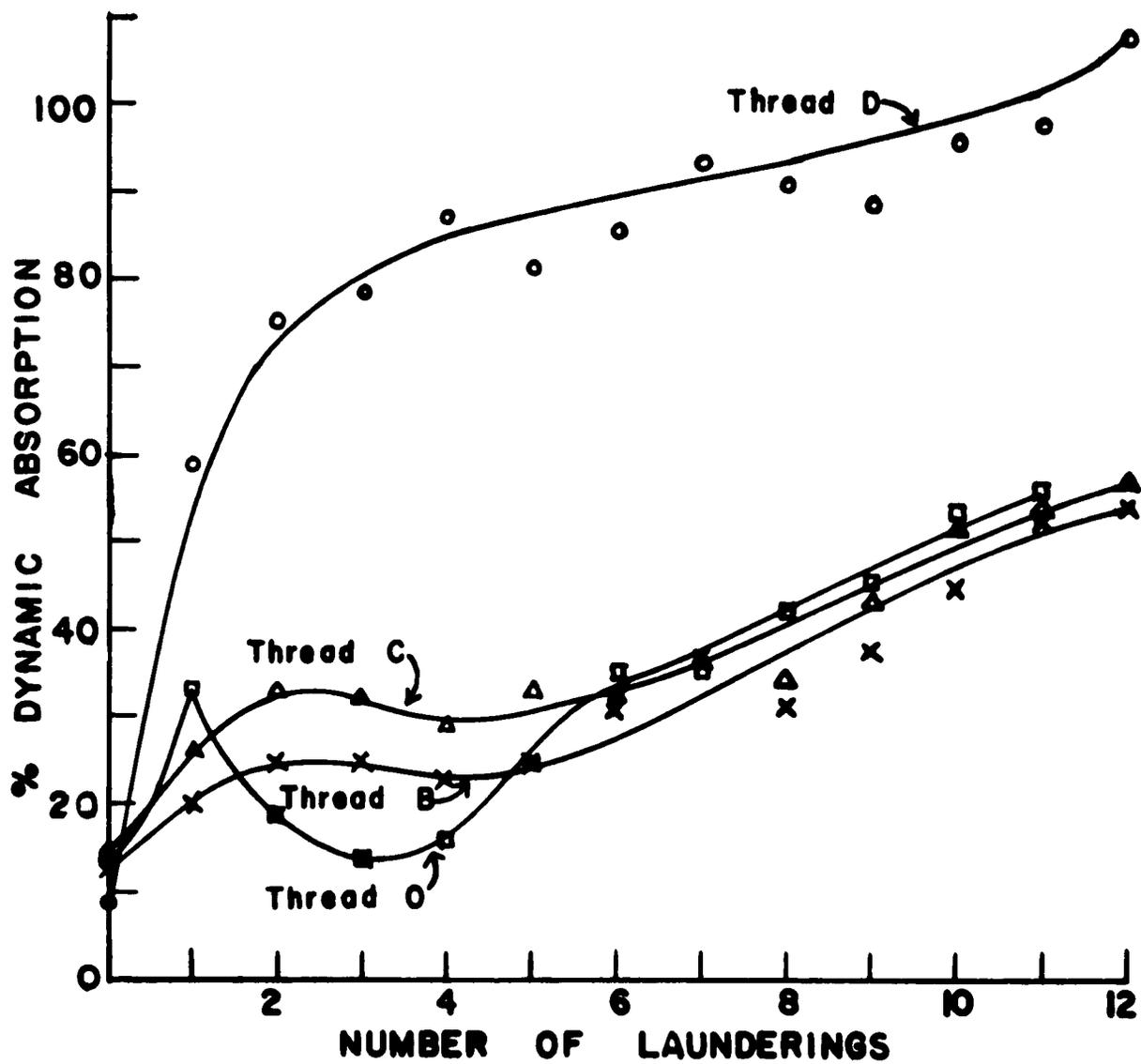


Figure 5. Dynamic Absorption Results of 12 Launderings of Quarrel-Treated Thread

These data show that, after the first laundering cycle, the absorption of Thread D increased 50 percentage points over its initial absorption of only 9 percent. After the second laundering, the dynamic absorption increased an additional 17 percentage points. The absorption of Thread D continued to gradually increase after each laundering until it reached 108 percent after the 12th laundering. Threads B and C, on the other hand, showed only moderate increases in absorption after the first laundering and rather small increases after the second. The absorption of Thread C reached 58 percent after 12 laundering and that of Thread B 55 percent. The absorption of both of these threads was only about 50 percent that of Thread D after 12 laundering. Thread O was received after the first laundering cycle had been completed on the other three threads, so it entered the study at the second laundering and consequently was subjected to only 11 cycles. This thread increased in absorption from an initial 13 percent to 33 percent after one laundering. After the second laundering, absorption dropped to 19. It is believed that this decrease occurred because the thread had not been sufficiently rinsed after the Quarpel application before drying and curing. The absorption of this thread gradually increased again so that, after 11 laundering cycles, the absorption fell into the same range as that of Threads B and C. Thus it was observed that, of the four threads tested, Thread D had received a less effective treatment than the other three.

This modified mobile method of laundering appears to have merit in distinguishing the level of absorption of Quarpel-treated thread after laundering, but it must be recognized that a sewing thread cannot be expected to perform according to the same standards as a woven fabric. While the thread showed much higher rates of absorption after 12 repeated laundering than a fabric similarly treated, this is not necessarily attributable to the removal or destruction of the Quarpel. The mechanical action of the dynamic absorption tests, the laundering cycles, and the handling of the thread all tended to disrupt the set of the thread twist and to alter the thread surface. Thus, while the total moisture held by the skein might be considered high, it is likely that most of this moisture was held mechanically by the skein structure rather than by absorption into the cotton fibers.

c. Physical damage incurred by laundering and handling the thread

After the first five laundering cycles, visible damage to the thread structure was noted. As previously mentioned, the intent had been to run 15 consecutive laundering but so many of the strands of Thread D were broken by the time 12 cycles were completed that it was impossible to straighten out the skeins for proper wringing. Thread D showed very definite broken strands and Threads B, C, and O showed definite deterioration but not to the same extent as Thread D. After each laundering cycle and before testing for dynamic absorption, the threads showed definite declines in weight from that observed before the initial test; thus some of the increases in absorption could have been due to mechanically-held water. The straightening of the skeins after the 5th cycle was difficult

and became increasingly difficult with each laundering cycle. As a result, the efficiency of wringing declined and this also affected the final results. The foregoing suggests that it is impractical to launder and test skeins of thread for dynamic absorption 15 times.

From these observations it appears that two factors influenced or tended to bias the results: 1) the efficiency of drying the skeins after laundering and before testing for dynamic absorption, and 2) the deterioration of the thread caused by the mechanical action in the jars and by the handling of the thread during the uncabing, recabing, and weighing after each laundering.

Accordingly, tests were conducted in which drying was carried out to a measured degree and in which skeins were uncabled and recabled after a varying number of laundering cycles.

d. Variations in absorbency affected by method of drying laundered skeins

The method and temperature of drying water-repellent-treated cotton fabrics after laundering are known to influence their water- and moisture-pickup characteristics. To study the effect of drying and to select those test factors which might require precise control in order to avoid variability in results, it was decided to use two extreme methods of drying Quarpel-treated thread after laundering. Four skeins of the thread were taken from a single cone of 50,3 ply thread randomly selected from each of three pilot plant lots (X, Y, and Z). All of the skeins were cabled and laundered as outlined above. Half of the skeins were air dried to equilibrium by hanging them for approximately 24 hours under standard conditions for textiles (70°F/65% RH); the other half were oven dried at 120°C (248°F) to the bone dry state (as in the laundering cycle) and then allowed to reach equilibrium under standard conditions. Results are shown in Table XI and in Figure 6.

TABLE XI

DYNAMIC ABSORPTION OF AIR- AND OVEN DRIED
QUARPEL-TREATED THREAD AFTER LAUNDERING

<u>Thread Lot</u>	<u>Before Laundering (%)</u>	<u>After Laundering (%)</u>			
		<u>Air-Dried</u>	<u>Re-Dried in oven</u>	<u>Oven-Dried</u>	<u>Re-Dried in oven</u>
X	12	65	14	23	16
Y	14	41	10	12	11
Z	15	43	16	13	11

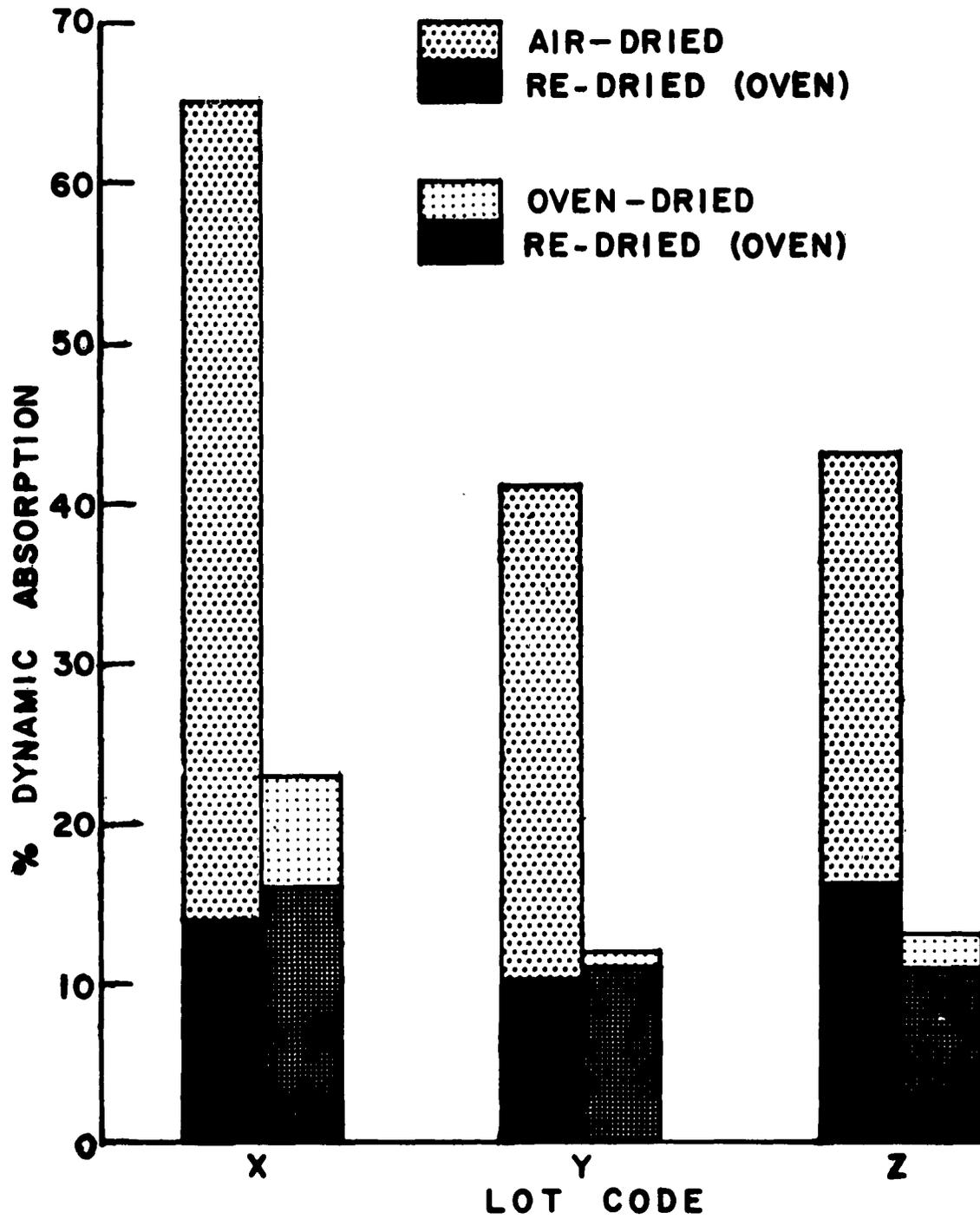


Figure 6. Dynamic Absorption Results of Air- versus Oven-Dried Quarpel-Treated Thread After Laundering

These data show that the air-dried skeins absorbed roughly three times as much moisture as the oven-dried skeins. Both methods distinguish between two levels of absorbency, represented by thread from Lot X on the one hand and threads from Lots Y and Z on the other. After re-drying in an oven, the air-dried specimens were brought to approximately the same absorption level as the oven-dried, although some difference still remained between threads from Lot X and threads from the other two lots.

To further study the effect of drying, one skein of threads D, C, B, and O, which had been tested for 12 launderings (see Table X), was again tested after being oven dried at 120°C (248°F) and then exposed to standard conditions until equilibrium was reached. The results are shown in Table XII.

TABLE XII

DYNAMIC ABSORPTION OF QUARPEL-TREATED THREAD AFTER LAUNDERING AND RE-DRYING

<u>Thread Code</u>	<u>After 12 Launderings Subjective Drying*</u> (%)	<u>Controlled Oven Re-Drying**</u> (%)
D	105	61
C	56	33
B	50	35
O	53	30

* Felt dry to hand.

** Until no change in weight was reached.

After re-drying, Thread D, which had demonstrated poor treatment initially, still was approximately twice as absorbent as the other threads. However, the controlled oven re-drying substantially reduced the levels of absorption of all the threads by from 30 to 40 percent.

From this study it was concluded that controlled mechanical (i.e., oven) drying (to a bone-dry state) of skeins of Quarpel-treated threads and then conditioning them at standard conditions gives more realistic and reliable results than air drying or partially-controlled drying. On the basis of these data, controlled drying as just described was used in all subsequent testing.

e. Effect of uncabbling and handling skeins after various cycles of laundering

In order to test the effect of cabling and recabbling after laundering and dynamic absorption testing, a limited experiment was conducted in which four skeins from each of three different cones from four lots of thread were entered simultaneously into laundering cycles. The skeins were numbered and skein #1 withdrawn after 1 laundering, skein #2 after 2 laundering, skein #3 after 5 laundering and skein #4 after 12 laundering. The skeins were rinsed, oven dried at 120°C (248F), conditioned at 70°F/65% RH, and tested for dynamic absorbency. The results are shown in Table XIII and in Figure 7, where each value represents a single test only.

TABLE XIII

COMPARISON OF THE DYNAMIC ABSORPTION OF QUARPEL-TREATED SKEINS OF THREAD AFTER EACH OF 1, 2, 5, AND 12 LAUNDERINGS

<u>Skein No.</u>	<u>No. of Launderings</u>	<u>Thread D</u> (%)	<u>Thread C</u> (%)	<u>Thread B</u> (%)	<u>Thread O</u> (%)
1	1	21	13	12	14
2	2	34	11	10	21
3	5	56	18	20	30
4	12	59	31	21	36

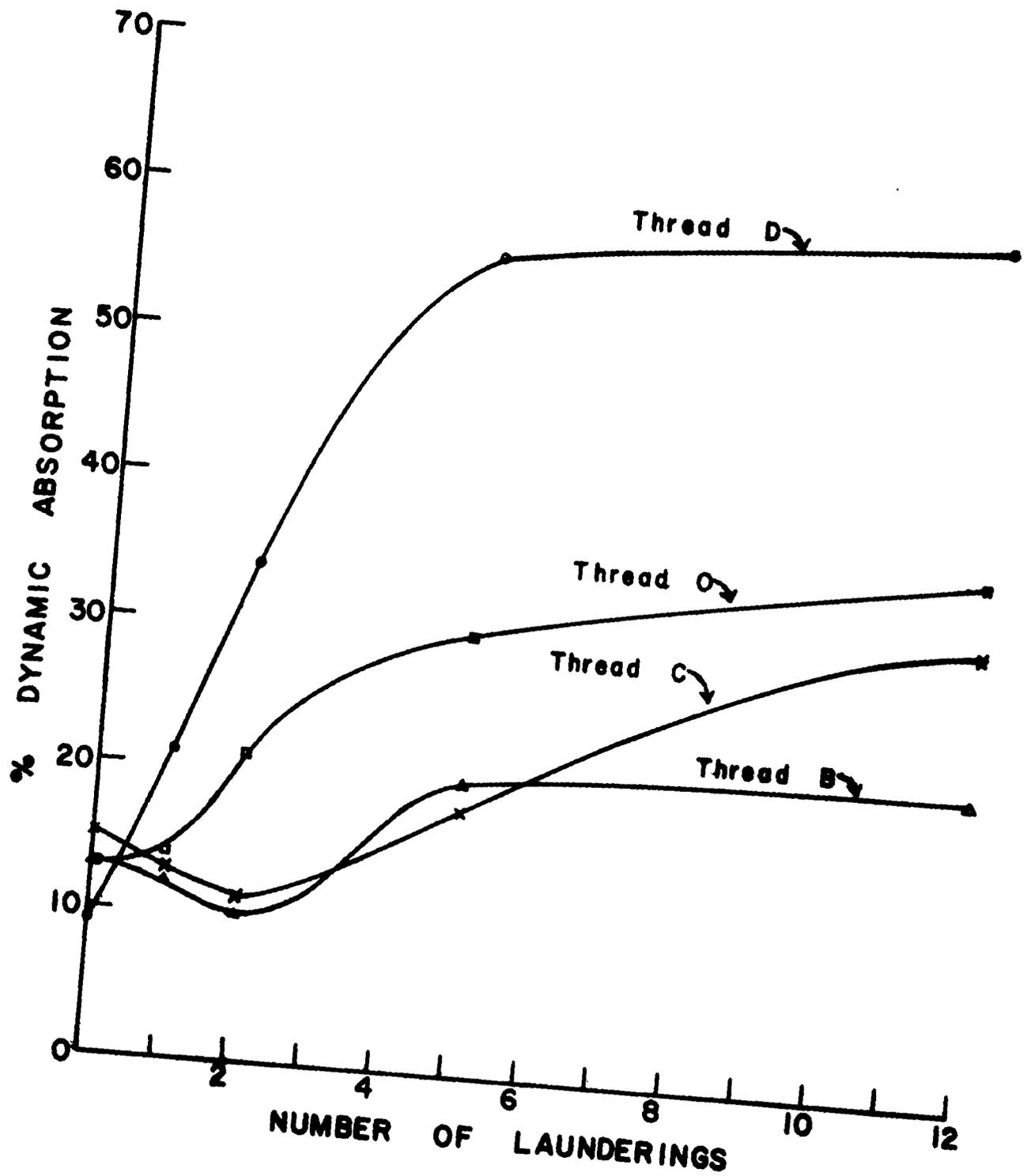


Figure 7. Dynamic Absorption Results Before and After 1, 2, 5 and 12 Launderings of Four Lots of Thread

These data show that, regardless of the added handling of the skeins in multiple launderings, the difference in water-absorbency level remained. Thread D continued to be characteristically poor. The data, when compared to those in Table X, also indicate that the amount of handling is not as important as the method of drying, for only Thread B showed a marked difference. It will be noted, however, that in Figure 7 all of the threads with the exception of C showed a leveling trend of absorbency after the 5th laundering. As pointed out previously, these results are from only one skein, hence no conclusions can be drawn from them. For quality control purposes, it is indicated that there is no advantage in measuring the dynamic absorption of threads between laundering cycles.

f. Comparison of three types of launderings

To further test whether or not the Launder-Ometer method of testing threads for dynamic absorption has any correlation with the Launder-Ometer method of testing Quarpel-treated fabrics, studies were made in which the skeins of thread were tested for dynamic absorption:

- (a) after each of 5 consecutive laundering cycles in the Launder-Ometer,
- (b) after only the 5th laundering cycle in the Launder-Ometer, and
- (c) after the 5th and 15th cycles of consecutive mobile launderings.

New threads which had been treated in the pilot-plant size lots by various manufacturers were used. The results of this testing are given in Table XIV and Figure 8.

TABLE XIV
DYNAMIC ABSORPTION (%) OF QUARPEL-TREATED THREADS
BEFORE AND AFTER 3 TYPES OF LAUNDERING

	Threads				
	<u>J</u>	<u>H</u>	<u>L</u>	<u>K</u>	<u>N</u>
Before Laundering	14	14	11	15	11
a. After each of 5 Launder-Ometer cycles*					
Cycle 1	22	26	17	21	11
" 2	32	32	23	25	10
" 3	35	35	25	29	13
" 4	38	39	33	29	21
" 5	41	43	36	34	31
b. After one unwinding following 5th Launder-Ometer cycle	43	46	43	34	31
c. After one unwinding following 5th mobile laundering cycle	39	42	36	29	37
After 15th mobile laundering cycle	56	61	56	43	57

* Skeins were unwound and recabled after each cycle.

Note: Each figure is the average of three tests.

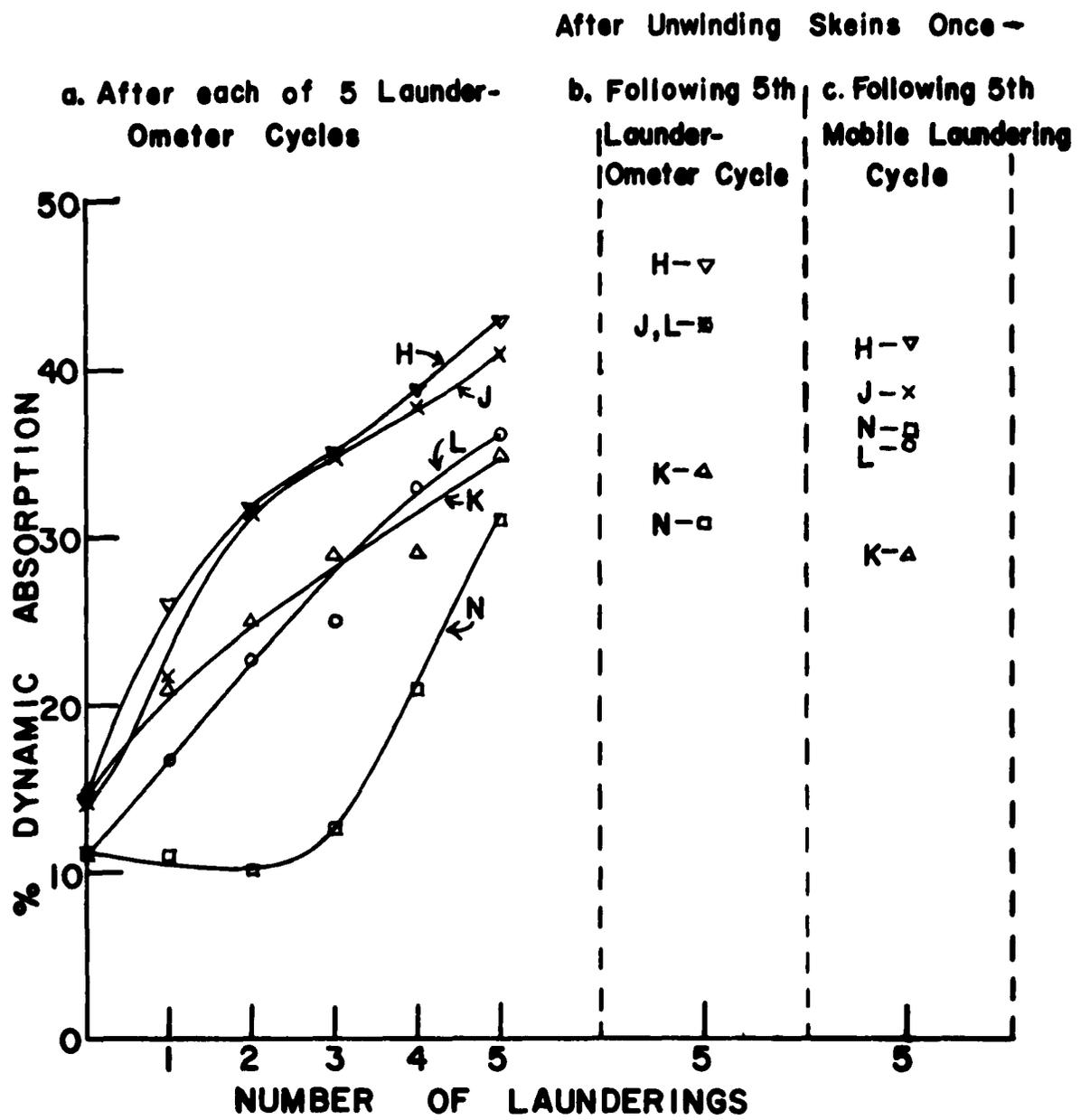


Figure 8. Dynamic Absorption Results of Three Method of Laundering

The two sets of data from launderings a and b show very good Launder-Ometer agreement after 5 cycles and indicate that the handling and testing of the skeins between laundering cycles does not adversely affect the results. Actually, three of the five threads had lower absorption values when tested after each laundering and two threads had the same value. The data are too limited to lend themselves to statistical analysis, hence the difference or lack of difference cannot be construed as a trend. However, the similarity of the results from both procedures does indicate that these methods of laundering and testing for dynamic absorption are reproducible and fairly precise when performed under a specific set of conditions and by the same operator.

The tests made after five mobile launderings gave results that compare favorably with those obtained after five Launder-Ometer cycles. However, with the exception of thread N, all of the mobile laundering values tended to be lower than those of the Launder-Ometer.

8. Conclusions

The data presented in this report warrant the following conclusions:

1. Quarpel can be applied to cotton sewing thread to produce water-repellent characteristics with a durability not found in any of the known commercial water repellents.
2. The best results are now obtained when the thread is treated in skein form, but it is quite likely that a satisfactory method of treating in package form will be worked out ultimately.
3. The physical properties of cotton thread are not adversely affected by the Quarpel treatment.
4. The durability of the water-repellent characteristics of Quarpel-treated thread does not approach that of a Quarpel-treated fabric, but this is believed to be a matter of material rather than finish.
5. The tumbling method of testing for dynamic absorption has been shown to be very hard on the thread and its action is probably more severe than that which would be encountered by the seams of a garment during wear.
6. Dynamic absorption determined by means of a Launder-Ometer gives water repellency results equivalent to those obtained in the 6-liter tumbling jar specified by Method 4500 of Specification CCC-T-191b. The Launder-Ometer permits the testing of as many as 20 skeins at a time.

9. Present Status

As a result of the foregoing study, levels of initial water repellency of 20 percent before laundering (tested in accordance with the Proposed Method: Water Absorption; Sewing Thread; Dynamic Method, Appendix C) and 30 percent after three consecutive launderings (conducted in accordance with the Proposed Laundering Procedure for Water-Repellent Thread, Appendix D) have been recommended for specification action on Quarpel-treated thread.

10. Acknowledgements

Appreciation is expressed to the several members of the thread industry who participated in the treating and testing of Quarpel thread.

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11. Literature Cited

Journal Articles and Reports

1. Frederick, Edward B., and Walter Zagieboylo. Water Repellent Thread for Military Items. QM R&E TS Report 87, Natick, Mass., 1955
2. Kennedy, S. J. New Horizons in Multi-Purpose Finishes for Military Clothing. Paper presented at AATT Meeting, New York City, 2 Dec 1959
3. DeMarco, Carlo G., Gil M. Dias, and William F. Smith. "Quarpel" Water and Oil Resistant Treatment for Textiles. QM R&E TS Report 111, Natick, Mass., 1960
4. Brown, Earline L., and Edward B. Frederick. Study of the Mechanism of Seam Leakage in Raincoat, Man's, Lightweight, Taupe, 197. QM R&E TEL Report 251, Natick, Mass., 1959
5. Federal Standard 751, Stitches, Seams, and Stitchings. Washington 25, D.C., 1959

Patents

6. U.S. Patent Office 3,034,925. Water-Resistant and Oil-Resistant Fibrous Substances, and Processes Therefor. 15 May 1962
7. U.S. Patent Office 3,042,642. Aqueous Textile Coating Composition Containing a Perfluoroalkyl Acrylate and a Methyl Pyridinium Halide. 3 July 1962

APPENDIX A

METHOD 4500 OF CCC-T-191b:
WATER ABSORPTION; SEWING THREAD; DYNAMIC METHOD

1. SCOPE

1.1 This method is intended for determining the amount of water absorbed by sewing thread when subjected to dynamic conditions.

2. TEST SPECIMEN

2.1 The specimen shall be 4 to 6 grams of the thread prepared in the form of a skein.

3. APPARATUS; METHOD CITED

3.1 Apparatus

3.1.1 Apparatus as described in method 5500.

3.1.2 Yarn reel or other suitable device for preparing a skein.

3.2 Method Cited

Method 5500, Water resistance of cloth; dynamic absorption method.

4. PROCEDURE

4.1 Unless otherwise specified in the material specification, the tumble jar shall be rotated for 10 minutes.

4.2 The specimen shall be conditioned and weighed to 0.1 gm. One liter of distilled water at a temperature of $26.7^{\circ} \pm 1^{\circ}\text{C}$. ($80^{\circ} \pm 1.8^{\circ}\text{F}$.) shall be placed in the tumble jar and weighed specimen put in water and the jar rotated for the required time at a speed of 55 ± 2 r.p.m.

4.3 At the end of the rotating time the specimen shall be removed from the water, run through the rolls once without blotters, and then immediately one time between unused blotters.

4.4 The specimen shall be immediately weighed to the nearest 0.1 gm., care being taken to keep the evaporation of moisture from the specimen to a minimum.

4.5 Calculation of results.- The dynamic absorption shall be calculated as follows:

$$\text{Dynamic absorption, percent} = \frac{F - O}{O} \times 100$$

where:

O = original conditioned weight of the specimen, 4.2

F = final weight of the specimen, 4.4

5. REPORT

5.1 Unless otherwise specified in the material specification, three specimens shall be tested from each Unit-of-Product.

5.2 The dynamic absorption of the Unit-of-Product shall be the average of the results obtained from the specimens tested and shall be reported to the nearest 1.0 percent.

APPENDIX B

PROPOSED METHOD:
WATER ABSORPTION; SEWING THREAD; DYNAMIC METHOD

1. SCOPE

1.1 This method is intended for determining the amount of water absorbed by sewing thread when subjected to dynamic conditions.

2. TEST SPECIMEN

*2.1 The test specimen shall be a 5 ± 0.5 gram skein made on a 54 inch periphery skein reel. The skein shall be folded flat then twisted around its long axis for a total of 25 turns in the same direction as that of the final ply twist of the thread. The two ends shall be brought together and the folded skein allowed to back twist on itself. The ends shall be tied off to prevent untwisting in the tumbling and rinsing.

3. APPARATUS: METHOD CITED

3.1 Apparatus

3.1.1 Apparatus as described in Method 5500.

3.1.2 Yarn reel or other suitable device for preparing a skein.

*3.1.3 A twist tester or other suitable device for twisting the skeins.

3.2 Method cited.

Method 5500, Water resistance of cloth; dynamic absorption method.

*3.3 Blotting Paper - Blotting paper as described in Method 5500 except that the dimensions shall be 4 x 30 inches.

3.4 Laboratory Balance - A laboratory balance shall be accurate to 0.01 gm.

4. PROCEDURE:

4.1 Unless otherwise specified in the material specification, the tumble jar shall be rotated for 10 minutes.

*4.2 The specimen shall be conditioned and weighed to 0.01 gm. One liter of distilled water at a temperature of $26.7^{\circ} \pm 1^{\circ}\text{C}$. ($80^{\circ} \pm 1.8^{\circ}\text{F}$) shall be placed in the tumble jar and weighed specimen put in water and the jar rotated for the required time at a speed of 55 ± 2 r.p.m.

* Paragraph changed.

*4.3 At the end of the rotating time the specimen shall be removed from the water, untwisted, straightened out and run through the wringer once without blotters. Then immediately placed inside a folded unused blotter (2 x 30), run through the wringer a second time.

*4.4 The specimen shall be immediately weighed to the nearest 0.01 gm., care being taken to keep the evaporation of moisture from the specimen to a minimum.

4.5 Calculation of results - The dynamic absorption shall be calculated as follows:

$$\text{Dynamic absorption, percent} = \frac{F - O}{O} \times 100 \text{ where:}$$

O = original conditioned weight of the specimen, 4.2
F = final weight of the specimen, 4.4

5. REPORT

*5.1 Unless otherwise specified in the material specification, two specimens shall be tested from each Unit-of-Product.

5.2 The dynamic absorption of the Unit-of-Product shall be the average of the results obtained from the specimens tested and shall be reported to the nearest 1 percent.

* Paragraph changed.

APPENDIX C

PROPOSED METHOD: WATER ABSORPTION; SEWING THREAD; LAUNDER-OMETER METHOD

1. SCOPE

1.1 This method is intended for determining the amount of water absorbed by sewing thread when subjected to dynamic conditions in the Launder-Ometer.

2. TEST SPECIMEN

2.1 The test specimen shall be a 5 ± 0.5 gram skein made on a 54 inch periphery skein reel. The skein shall be folded flat then twisted around its long axis for a total of 25 turns in the same direction as that of the final ply twist of the thread. The two ends shall be brought together and the folded skein allowed to back twist on itself. The ends shall be tied off to prevent untwisting in the tumbling and rinsing.

3. APPARATUS: METHOD CITED

3.1 Apparatus

3.1.1 The apparatus shall be a Launder-Ometer or similar machine in which tightly capped one-pint jars are held with their bases toward a horizontal shaft 2 inches from the center of rotation, with the shaft rotating at a speed of 40 to 45 r.p.m. Provision shall be made for maintaining the required temperature in the contents of the jar within $\pm 1^{\circ}\text{C}$ (1.8°F).

3.1.2 Twenty rubber balls $3/8$ inch in diameter shall be placed in each jar.

3.1.3 Water shall not exceed a total hardness of 35 parts/million calculated as calcium carbonate (CaCO_3).

3.1.4 Wringer as described in Method 5500.

3.1.5 Yarn reel or other suitable device for preparing a skein.

3.1.6 A twist tester or other suitable device for twisting the skeins.

3.1.7 Blotting paper as described in Method 5500 except that the dimensions shall be 4 x 30 inches.

3.1.8 Laboratory balance accurate to 0.01 gm.

3.2 Method cited

3.2.1 Method 5500, Water resistance of cloth; dynamic absorption method.

4. PROCEDURE

4.1 The specimen shall be conditioned and weighed to 0.01 gm.

4.2 In each jar of the Launder-Ometer, 100 ml. of water, at a temperature of $26^{\circ}\text{C} \pm 1^{\circ}\text{C}$ ($78.8^{\circ} \pm 1.8^{\circ}\text{F}$), and twenty rubber balls shall be placed with a skein.

4.3 The jar shall then be agitated for 30 minutes at a temperature of $26^{\circ}\text{C} \pm 1^{\circ}\text{C}$ ($78.8^{\circ} \pm 1.8^{\circ}\text{F}$) in the Launder-Ometer at a speed of 40 to 45 r.p.m.

4.4 At the end of the rotating time the specimen shall be removed from the water, untwisted, straightened out and run through the wringer once without blotters, then immediately placed inside a folded unused blotter (2 x 30 inches) and run through the wringer a second time.

4.5 The specimen shall be immediately weighed to the nearest 0.01 gm., care being taken to keep the evaporation of moisture from the specimen to a minimum.

4.6 Calculation of results - The dynamic absorption shall be calculated as follows:

Dynamic absorption, percent = $\frac{F - O}{O} \times 100$ where:

O = original conditioned weight of the specimen, 4.1

F = final weight of the specimen, 4.5

5. REPORT

5.1 Unless otherwise specified in the material specification, two specimens shall be tested from each Unit-of-Product.

5.2 The dynamic absorption of the Unit-of-Product shall be the average of the results obtained from the specimens tested and shall be reported to the nearest 1 percent.

APPENDIX D

PROPOSED LAUNDERING PROCEDURE
FOR WATER-REPELLENT THREAD

1. SCOPE

1.1 This method is intended for determining the durability of water-repellent thread to laundering.

2. TEST SPECIMEN

2.1 The specimen size shall be a 5 (+ 0.5) grams skein prepared the same as specified for dynamic absorption testing (Method 4500).

3. APPARATUS; REAGENTS; METHOD CITED

3.1 Apparatus

3.1.1 The apparatus shall be a Launder-Ometer or similar machine in which tightly capped one-pint jars are held with their bases toward a horizontal shaft 2 inches from the center of rotation, with the shaft rotating at a speed of 40 to 45 r.p.m. Provision shall be made for maintaining the required temperature in the contents of the jar within $\pm 1^{\circ}\text{C}$. (1.8°F).

3.1.2 20 rubber balls $3/8$ inch in diameter shall be placed in each jar.

3.1.3 Water shall not exceed a total hardness of 35 parts/million calculated as calcium carbonate (CaCO_3).

3.1.4 A circulating-air oven capable of maintaining the required temperature within $\pm 1^{\circ}\text{C}$ (1.8°F) shall be used.

3.2 Reagents

3.2.1 A 1.0 percent IGepon T73 solution (10 gms/liter).

3.3 Method cited

3.3.1 Method 4500, Water absorption, sewing thread; dynamic method.

3.3.2 Method 5500, Water resistance of cloth; dynamic absorption method.

4. PROCEDURE

- 4.1 Unless otherwise specified, the temperature of the water during the test shall be maintained at $71^{\circ} \pm 1^{\circ}\text{C}$ ($159.8^{\circ} \pm 1.8^{\circ}\text{F}$).
- 4.2 The specimen assembly shall be placed in the 1-pint jar containing 100 ml of a 1.0 percent IGepon T73 solution (10 gms/liter) at a temperature of $71^{\circ} \pm 1^{\circ}\text{C}$ ($159.8^{\circ} \pm 1.8^{\circ}\text{F}$) and the 20 rubber balls.
- 4.3 The jar shall then be agitated for 45 minutes at the required temperature in the Launder-Ometer or similar machine at a speed of 40 to 45 r.p.m.
- 4.4 At the end of the laundering period, the specimen shall be removed from the jar and rinsed thoroughly in running water at a temperature of $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 1.8^{\circ}\text{F}$) and agitated occasionally during rinsing. Care should be taken in the rinses to insure that all traces of detergent are removed as this will have a deleterious effect on dynamic absorption results.
- 4.5 The specimen shall be wrung or extracted and oven dried at a temperature of 105 to 110 degrees C (221 to 230F) until thoroughly dry. The skein shall then be exposed to standard conditions for testing textiles until equilibrium is reached and then weighed. This weight shall be used as the base for calculating the percent dynamic absorption after laundering.
- 4.6 The laundered skeins shall be tested for dynamic absorption in accordance with Methods 4500 and 5500 of CCC-T-191.

5. REPORT

- 5.1 Unless otherwise specified in the material specification, two specimens shall be tested from each Unit-of-Product.
- 5.2 Unless otherwise specified in the material specification, the thread shall be reported as satisfactory when the dynamic absorption after laundering does not exceed a maximum absorption of 30 percent.

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