# A COMPARISON OF THE HEAT RETAINING PROPERTIES OF CERTAIN BLANKETS OF VARIOUS FIBER CONTENT

by

PEARL ADELL GILMORE

B. S., University of Minnesota, 1942

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A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Clothing and Textiles

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1944

A11202 485192

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# INTRODUCTION

"All wool and a yard wide" has been a standard by which many consumers have judged quality when buying fabrics. Wool was accepted as the best fiber for use in fabrics where warmth was desired before people understood that it had the property of entrapping and holding air. These dead air spaces within the fabric were believed by early investigators to determine the thermal insulating value of blankets. In recent years thickness has been considered an important factor in influencing the heat insulating property of a blanket.

The property of wool fibers which makes a blanket maintain its fluffiness during use and care has been accredited to resiliency, the ability of a fiber to spring back when compressed. The wool fiber was once considered the most resilient of fibers but now it is believed that other fibers may equal wool in this quality.

The effects of fiber content, laundering, dry cleaning, and storage on the resiliency and thermal conductivity of blankets are important considerations about which little information is available to the consumer. Today the demand of the armed forces has accelerated the use of fibers other than wool in the manufacture of household blankets. Consequently, information on the service qualities of blankets of different fiber content is timely.

This study was made to determine the effects of fiber content, laundering, dry cleaning, and storage on thermal conductivity and resiliency of certain selected blankets.

## REVIEW OF LITERATURE

No studies were found that compared the effect of laundering, dry cleaning, and storage on resiliency and thermal conductivity of blanket materials. However, many investigators have made thermal conductivity studies of various fabrics.

One of the early investigators, Haven, as reported by Armory (1) believed that the thermal insulating value of a fabric depended upon the dead air spaces within it. Tests made by Lewis were described in the same article. Lewis washed the wool and the cotton blankets twice and tested them each time for thermal insulating value. Cotton blankets were found to be as warm as wool and wool in cotton blankets did not add to the warmth. Lewis agreed with Haven that thermal insulation depended upon the dead air spaces within the blanket.

From other studies thickness was reported as the principal factor in the heat insulation of blankets. Marsh (5) tested the thermal insulating properties of blankets of cotton and wool and those of all-wool. The weaves of the blankets were plain, four shaft satin, twill, and double plain. Marsh concluded that the thickness was the principal factor in the insulating value of a blanket.

In a study made on heat insulation and related properties of blankets at the United States Bureau of Standards by Sale and Hedrick (7) a correlation was found between thickness and thermal resistance. Of two fabrics equally good as to heat insulation the more desirable would be the one which was more permeable to air and water vapor because it would facilitate ventilation and the escape of evaporated moisture.

Schiefer (11) studied the factors relating to thermal insulation of fabrics and found that the kind of fiber appears to have no effect on thermal insulation, but that resilience helps a fabric to keep its original thickness and thus affects the thermal insulation of a fabric.

The effect of laundering on thermal conductivity has been investigated to a certain extent. Schiefer, Mizell, and Mosedale (12) made studies of 33 blankets of eight different constructions in which all-wool army blankets were compared with blankets of wool and cotton mixtures. One blanket of each construction was laundered 10 times and not renapped. Before laundering the part-wool blankets were more compressible, thicker, and had greater insulating value than the all-wool blankets. The part-wool blankets shrank nearly twice as much as the regular all-wool army blanket, necessitating an increase in the original size. After laundering there was an increase in thickness and a decrease in compressibility and heat transmission of all blankets due to shrinkage. Hays and Elmquist (4) also stated that the heat transmission of wool blankets tended to decrease as the number of service periods increased; therefore, laundered blankets were warmer than new ones.

## METHOD OF PROCEDURE

Nine blankets were used for this study, three all-wool, two wool and cotton, one wool and rayon, one wool, cotton, and rayon, and two cotton and rayon blankets. For means of identification each blanket was given a number and a letter or letters indicating fiber content - W for wool, C for cotton, and R for rayon. The retail price and size of these blankets are given in Table 1.

Table 1. Blankets used in this study.

| Number | Fiber content | Price | Size | Labeled size |
|---|---|---|---|---|
| 1 W | Wool | $ 9.00* | 62 x 82 | - |
| 2 W | Wool | 9.00* | 63 x 82 | - |
| 3 W | Wool | 18.00* | 75 x 90 | - |
| 4 WR | Wool and rayon | 5.95 | 75 x 92 | 72 x 92 |
| 5 WRC | Wool, rayon, and cotton | 6.95 | 72½x 82½ | 72 x 84 |
| 6 WC | Wool and cotton | 5.00* | 64 x 82 | - |
| 7 WC | Wool and cotton | 4.98 | 64 x164½ | 72 x 84 |
| 8 CR | Cotton and rayon | 5.00* | 74 x 89 | 72 x 90 |
| 9 CR | Cotton and rayon | 4.79 | 70½x 82 | 72 x 84 |

* Estimated price, blankets obtained for a former study.

## EXPLANATION OF PLATE I

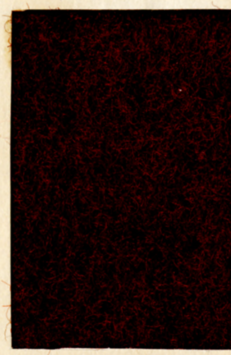
Blankets used in this study

1. 1 W wool
2. 2 W wool
3. 3 W wool
4. 4 WR wool and rayon
5. 5 WRC wool, rayon, and cotton
6. 6 CW cotton and wool
7. 7 CW cotton and wool
8. 8 CR cotton and rayon
9. 9 CR cotton and rayon

# PLATE I

1

2



3

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7

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9

Fiber content, breaking strength, thread count, thickness, weight per square yard, and per cent of finish were determined by standard methods as described in the Standards on Testing Materials of the American Society for Testing Materials (Table 3).

## Determination of Thermal Conductivity

Thermal conductivity tests were made on all blankets in their original state, after five launderings, five dry cleanings, and two and one-half months of storage. The Cenco Fitch thermal conductivity apparatus was used for these tests. This apparatus consists of a calorimeter maintained at constant temperature with boiling water and a cold receiving plate connected to the calorimeter with a galvanometer in the circuit.

The calorimeter was adjusted to the height equal to the thickness of the blanket being tested. It was then filled with water which was kept at the boiling point by means of an immersion heater. The fabric was placed between the two plates of different temperatures and the flow of heat through the fabric was measured by deflections on the galvanometer. The readings were taken every minute for 10 minutes. Readings were taken on five different positions on each specimen. The average of these five readings was plotted on semi-logarithmic paper using the galvanometer readings as the abscissa and the time in minutes as the ordinate. A straight line was drawn through these points. The point at which this line or an extension of this line intersected the horizontal line at 27 was used to compute the results of the tests.

Because the variation within one specimen for each laundering and each dry cleaning was greater than the variation between launderings or dry cleanings, it was difficult to distinguish one line from another in a graph. Therefore, the readings of the fifth laundering and the fifth dry cleaning were plotted (Plates II, III, IV). The time obtained from these graphs was used to calculate the thermal conductivity. Thermal conductivity was measured in terms of coefficient of heat transmission and conductance. The coefficient of heat transmission is the number of calories per centimeter per second per degree centigrade that passes through a material. This is also referred to as coefficient of thermal conductivity and is represented by the letter "k". The formula, $k = \frac{\text{Constant x thickness}}{\text{time in minutes}}$ intercept in which the constant equaled .0093[1], compensated for thickness of a blanket that is in a fraction of an inch so that the effect of fiber content can be compared even though the blankets differ in thickness. In other words, if all the blankets were one centimeter in

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[1] Letter, May 31, 1944, from Mr. E. A. Schwarz, Textile Technology.

thickness, the coefficient of thermal conductivity would indicate the influence of fiber content and the structure of the fabrics. The coefficient of heat transmission was used to compare the thermal conductivity of the blankets in the original state (Fig. 1).

Thermal conductivity determined in terms of conductance from the formula of C = Constant XL / ~~time in minutes~~ intercept, in which the constant equaled .0037[1] did not compensate for the variation in thickness; hence, it permitted a comparison of the effect of cleaning and storage on the individual blankets. Results of such calculations were used for this comparison (Fig. 2).

## Determination of Resiliency

Resiliency of the blankets was measured by means of a Saxl Compressometer. This apparatus consists of a plunger attached to a pinion drive and vernier on a support rod. All are mounted on one base which has leveling screws. Four specimens of a blanket were arranged lightly one on top of another and placed upon the balance platform. The apparatus was brought into balance and the plunger adjusted to touch the top specimen without throwing the pointer off the balanced position; this indicated that no pressure was applied to the specimen by the plunger. Weights of five, 10, 25, 50, 100, on up to 1,000 g at intervals of 100 g were consecutively applied, causing the specimen to be forced against the plunger. In depressing the plunger into the specimens by means of the vernier screw the balance of the apparatus was regained. In this manner pressure equal to the weight on the arm was applied to the specimen. The depth of the depression of the plunger for each weight applied was read on the vernier and tabulated. This method was reversed thus obtaining first the loading and then the deloading cycle. Thirty seconds were allowed to elapse after each application of weight and depression of the plunger before recording the reading. The percentage of resiliency was calculated from these data by the formula: $\%R = \frac{a-b}{a}$ in which R equals the resiliency, a is the total depth of depression at 1,000 g pressure, and b is the returned height with no weight applied.

## Determination of Thickness

Thickness was measured with the cathetometer and compared with results obtained with the compressometer. Four specimens were placed lightly one on top of another to determine whether the weight of the three specimens reduced the thickness of the bottom one. These were measured on all four sides with the cathetometer. There was greater variation within the thickness of one layer than between the thicknesses of the four specimens. Tests proved that the thickness obtained from the cathetometer varied but slightly with those of the compressometer. The Saxl Compressometer was used because thickness could be obtained at the same time that the resilience tests were made. Four thicknesses were placed on the platform and the apparatus brought into balance. The plunger was brought in touch with the top specimen without pressure as in the resilience tests. The specimens were removed from under the plunger and the plunger lowered by the pinion screw to touch the platform, keeping the balance pointer at zero. The depth of the four thicknesses of blanket was recorded. The thickness of one specimen was then calculated.

## Determination of Shrinkage and Restorability

The set of specimens prepared for shrinkage and restorability determinations were used for the tests on thermal conductivity and resilience of the fabrics after laundering. The specimens were prepared from 25 inch squares of the blankets taken 10 per cent or more of the width of the blanket away from the selvage. These were marked by means of a special template which permitted the marking of a 10-inch square for shrinkage determinations. The square was eccentrically located to provide two long and two short tabs required for the restorability tests. The template was placed on the 25-inch squares so as to allow two and three-fourths inches of the specimen to extend on all sides. The cloth was adjusted so that the warp and filling were parallel to the sides of the 10-inch square. The inside and outside edges of the template were marked with ink. These guide lines were later marked with thread for permanency in laundering. The direction of the warp and the number given the blanket were also permanently marked on each specimen.

Laundering of the blankets was done in a rotary electric washing machine with a capacity of 18 liters. A standing suds of two inches was obtained by using 45 g of a neutral soap with distilled water. The blankets were washed 10 minutes, maintaining the temperature at 90° F. or below, rinsed twice for one minute each in water at this same temperature. Excess moisture was removed by squeezing and the blankets were hung in the laboratory where the air was circulating.

After each laundering the 10-inch squares were measured both ways at three places and the percentage of shrinkage calculated.

Dimensional restorability tests were made by use of the United States Company Tension Presser. This consists of a flat bed with four clamp bars, two being fixed and two movable. The laundered fabric was wet thoroughly in distilled water, the excess water removed, and the fabric clamped into the tension presser. The two short tabs were placed in the fixed clamps and the two long tabs in the movable clamps. Weights were applied to hold the fabric at a fixed tension. The first weight applied was in the direction of the greatest change. Directions furnished with the apparatus (Table 2) gave the weight to be applied according to the amount of fabric shrinkage.

Table 2. Weights applied in restorability tests.

| Shrinkage | Weight to be applied |
|---|---|
| Any percentage gain and up to and including one percent loss | ½ pound |
| Over one percent and up to and including three percent loss | 1 pound |
| Over three percent and up to and including five percent loss | 3 pounds |
| Over five percent loss | 4 pounds |

Dry cleaning was done by a commercial establishment. Twelve-inch specimens were prepared and sewed together with strips of muslin to facilitate handling and to assure that all specimens received the same treatment. No attempt was made to restore these specimens to the original size. Within each specimen a 10-inch square was marked with thread. These squares were measured at three places in each direction after each cleaning and the average shrinkage was calculated.

# FINDINGS AND DISCUSSION

The blankets chosen for this study represented a group from which household blankets might be selected. They included blankets of all-wool and blends of various fibers. The price varied with fiber content and size of blanket as shown in Table 1.

The results of fabric analysis, fiber content, weave, breaking strength, elongation, weight per square yard and per cent of finish are shown in Table 3. These data showed great variation in service qualities as represented by breaking strength, and ounces per square yard, but there was little variation in the thread count. The range of thickness was .207 to .398 in. The percentage of finish varied from 1.24 to 4.8 per cent. The weave of the blankets was either twill or double.

## Thermal Conductivity

Galvanometer readings for thermal conductivity calculations (Table 4) were plotted on semi-logarithmetic paper (Plates II, III, IV) for all blankets in the original state, and after five launderings, five dry cleanings, and two and one-half months of storage. From data obtained from these graphs the coefficient of heat transmission was calculated

Table 3. Physical characteristics of the nine blankets used in this study.

| | Breaking strength (pounds) | | | | Elongation (per cent) | | | | Thread count | | Thickness inches | Weight per sq. yd. | Weight per 72x84 in. | Finish | Fiber content (per cent) | | | Weave |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry | | Wet | | Dry | | Wet | | | | | | | | | | | |
| Blanket | Warp | Filling | Warp | Filling | Warp | Filling | Warp | Filling | Warp | Filling | (no pressure) | (oz. dry wt.) | (lb. dry wt.) | (per cent) | Wool | Cotton | Rayon | |
| 1 W* | 22.5 | 7.5 | 15.1 | 7.9 | .69 | .78 | 1.50 | 1.4 | 21 | 21 | .219 | 8.56 | 2.50 | 1.70 | 100 | 0 | 0 | Twill |
| 2 W* | 22.7 | 4.6 | 15.4 | 4.4 | .61 | .87 | 1.53 | 1.2 | 23 | 21 | .244 | 7.94 | 2.32 | 2.73 | 100 | 0 | 0 | Twill |
| 3 W* | 27.5** | 31.0** | - | - | - | - | - | - | 24 | 22 | .398 | 17.92** | 5.33** | - | 100 | 0 | 0 | Double |
| 4 WR | 28.0 | 30.5 | 15.5 | 19.0 | .42 | .70 | .64 | .74 | 30 | 18 | .311 | 10.25 | 2.99 | 3.89 | 14.2 | 0 | 85.8 | Double |
| 5 WRC | 38.9 | 19.5 | 43.0 | 24.6 | .32 | .63 | .54 | .71 | 42 | 18 | .365 | 10.38 | 3.03 | 4.08 | 24.3 | 29.6 | 46.1 | Double |
| 6 WC* | 32.6 | 21.9 | 32.1 | 24.1 | .22 | .39 | .36 | .51 | 28 | 28 | .207 | 7.62 | 2.23 | 4.48 | 4.8 | 95.2 | 0 | Twill |
| 7 WC | 29.6 | 7.3 | 39.4 | 9.8 | .25 | .16 | .33 | .23 | 35 | 23 | .242 | 6.08 | 1.78 | 2.50 | 21.8 | 78.2 | 0 | Twill |
| 8 CR | 35.5 | 40.4 | 39.1 | 48.0 | .31 | .62 | .51 | .55 | 34 | 24 | .284 | 11.03 | 3.22 | 1.24 | - | 52.3 | 47.7 | Double |
| 9 CR | 37.4 | 26.9 | 36.5 | 17.5 | .44 | .64 | .44 | .73 | 37 | 21 | .319 | 10.65 | 3.11 | 4.80 | - | 49.1 | 50.9 | Double |

* Furnished by manufacturer for a previous study.
** Information from a previous study.

Table 4. Galvanometer readings used in thermal conductivity calculations of the blankets in this study.

| Time in minutes | Blankets in original state | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 W | 2 W | 3 W | 4 WR | 5 WRC | 6 WC | 7 WC | 8 CR | 9 CR |
| 0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| 1 | 30.0 | 29.5 | 29.0 | 29.5 | 29.5 | 29.5 | 30.0 | 30.0 | 29.5 |
| 2 | 29.5 | 29.5 | 22.0 | 29.5 | 29.5 | 29.0 | 29.5 | 29.5 | 29.5 |
| 3 | 29.0 | 29.0 | 29.0 | 29.0 | 29.5 | 29.0 | 29.5 | 29.5 | 29.0 |
| 4 | 29.0 | 29.0 | 28.5 | 29.0 | 29.0 | 28.5 | 29.0 | 29.5 | 29.0 |
| 5 | 29.0 | 29.0 | 28.5 | 29.0 | 29.0 | 28.5 | 29.0 | 29.0 | 29.0 |
| 6 | 29.0 | 28.5 | 28.0 | 29.0 | 29.0 | 28.0 | 29.0 | 29.0 | 28.5 |
| 7 | 28.5 | 28.5 | 28.0 | 28.5 | 29.0 | 28.0 | 29.0 | 29.0 | 28.5 |
| 8 | 28.5 | 28.0 | 28.0 | 28.5 | 29.0 | 27.5 | 28.5 | 29.0 | 28.5 |
| 9 | 28.0 | 28.0 | 28.0 | 28.5 | 28.5 | 27.5 | 28.5 | 29.0 | 28.0 |
| 10 | 28.0 | 28.0 | 27.5 | 28.0 | 28.5 | 27.0 | 28.0 | 29.0 | 28.0 |

| Time in minutes | Blankets laundered five times | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 W | 2 W | 3 W | 4 WR | 5 WRC | 6 WC | 7 WC | 8 CR | 9 CR |
| 0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| 1 | 29.5 | 29.5 | 30.0 | 30.0 | 29.5 | 30.0 | 29.5 | 29.5 | 29.0 |
| 2 | 29.5 | 29.5 | 29.5 | 30.0 | 29.5 | 29.5 | 29.0 | 29.0 | 28.5 |
| 3 | 29.0 | 29.0 | 29.5 | 29.5 | 29.5 | 29.0 | 28.5 | 29.0 | 28.0 |
| 4 | 29.0 | 29.0 | 29.5 | 29.5 | 29.0 | 29.0 | 28.5 | 28.5 | 28.0 |
| 5 | 29.0 | 29.0 | 29.5 | 29.5 | 29.0 | 29.0 | 28.0 | 28.5 | 27.5 |
| 6 | 28.5 | 28.5 | 29.0 | 29.0 | 29.0 | 29.0 | 27.5 | 28.0 | 27.0 |
| 7 | 28.5 | 28.5 | 29.0 | 29.0 | 29.0 | 28.5 | 27.5 | 28.0 | 26.5 |
| 8 | 28.5 | 28.5 | 29.0 | 29.0 | 29.0 | 28.0 | 27.0 | 27.5 | 26.0 |
| 9 | 28.5 | 28.0 | 29.0 | 29.0 | 29.0 | 28.0 | 26.5 | 27.0 | 26.0 |
| 10 | 28.0 | 28.0 | 28.5 | 29.0 | 28.5 | 28.0 | 26.0 | 27.0 | 26.0 |

| Time in minutes | Blankets dry cleaned five times | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 W | 2 W | 3 W | 4 WR | 5 WRC | 6 WC | 7 WC | 8 CR | 9 CR |
| 0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| 1 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| 2 | 30.0 | 30.0 | 30.0 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 |
| 3 | 30.0 | 29.5 | 30.0 | 29.5 | 29.5 | 29.0 | 29.5 | 29.5 | 29.5 |
| 4 | 29.5 | 29.5 | 30.0 | 29.5 | 29.5 | 29.0 | 29.0 | 29.0 | 29.0 |
| 5 | 29.0 | 29.5 | 29.5 | 29.5 | 29.5 | 28.5 | 29.0 | 29.0 | 29.0 |
| 6 | 29.0 | 29.0 | 29.5 | 29.0 | 29.5 | 28.0 | 29.0 | 29.0 | 29.0 |
| 7 | 29.0 | 29.0 | 29.5 | 29.0 | 29.5 | 28.0 | 28.5 | 29.0 | 29.0 |
| 8 | 29.0 | 29.0 | 29.5 | 29.0 | 29.0 | 28.0 | 28.5 | 28.5 | 28.5 |
| 9 | 28.5 | 29.0 | 29.5 | 28.5 | 29.0 | 27.5 | 28.0 | 28.0 | 28.5 |
| 10 | 28.5 | 29.0 | 29.5 | 28.5 | 29.0 | 27.0 | 28.0 | 28.0 | 28.0 |

| Time in minutes | Blankets stored two and one-half months | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 W | 2 W | 3 W* | 4 WR | 5 WRC | 6 WC | 7 WC | 8 CR | 9 CR |
| 0 | 30.0 | 30.0 | | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| 1 | 30.0 | 30.0 | | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| 2 | 29.5 | 30.0 | | 29.5 | 30.0 | 29.5 | 29.0 | 29.5 | 29.5 |
| 3 | 28.5 | 29.5 | | 29.5 | 30.0 | 29.5 | 28.5 | 29.0 | 29.0 |
| 4 | 29.0 | 29.0 | | 29.0 | 29.5 | 29.0 | 28.0 | 29.0 | 29.0 |
| 5 | 29.0 | 29.0 | | 29.0 | 29.5 | 29.0 | 27.5 | 28.5 | 28.5 |
| 6 | 29.0 | 29.0 | | 29.0 | 29.0 | 29.0 | 27.0 | 28.5 | 28.0 |
| 7 | 28.5 | 28.5 | | 29.0 | 29.0 | 28.5 | 27.0 | 28.0 | 28.0 |
| 8 | 28.5 | 28.5 | | 28.5 | 29.0 | 28.0 | 26.5 | 28.0 | 27.5 |
| 9 | 28.0 | 28.5 | | 28.5 | 29.0 | 28.0 | 26.0 | 27.5 | 27.0 |
| 10 | 28.0 | 28.0 | | 28.0 | 29.0 | 28.0 | 26.5 | 27.5 | 27.0 |

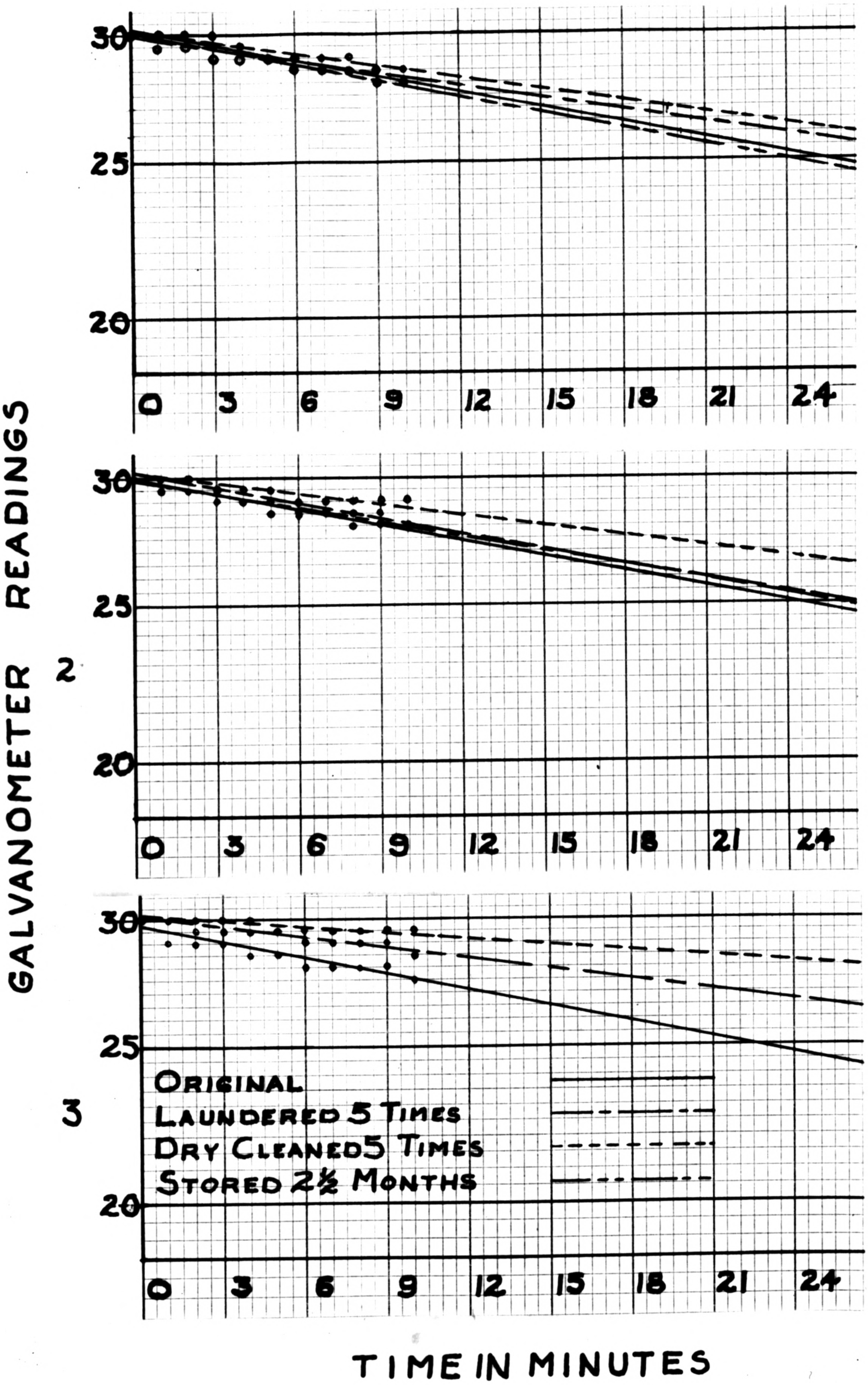
* Not enough fabric available for storage.

## EXPLANATION OF PLATE II

Thermal conductivity graphs

1. Blanket 1 W
2. Blanket 2 W
3. Blanket 3 W

# PLATE II

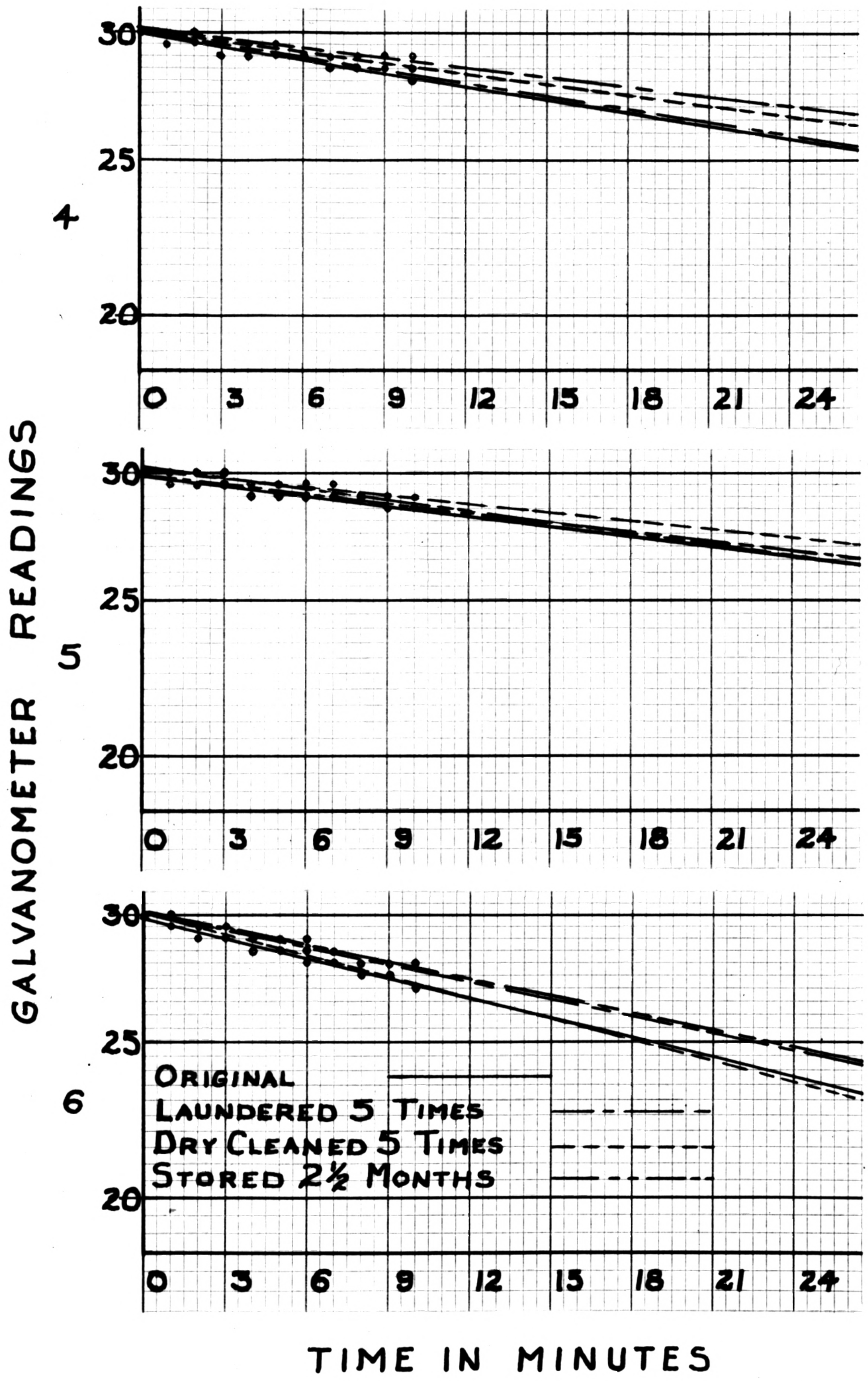

30
25
20
0
3
6
9
12
15
18
21
24
GALVANOMETER READINGS
2
3
ORIGINAL
LAUNDERED 5 TIMES
DRY CLEANED 5 TIMES
STORED 2½ MONTHS
TIME IN MINUTES

## EXPLANATION OF PLATE III

Thermal conductivity graphs

4. Blanket 4 WR
5. Blanket 5 WRC
6. Blanket 6 WC

# PLATE III

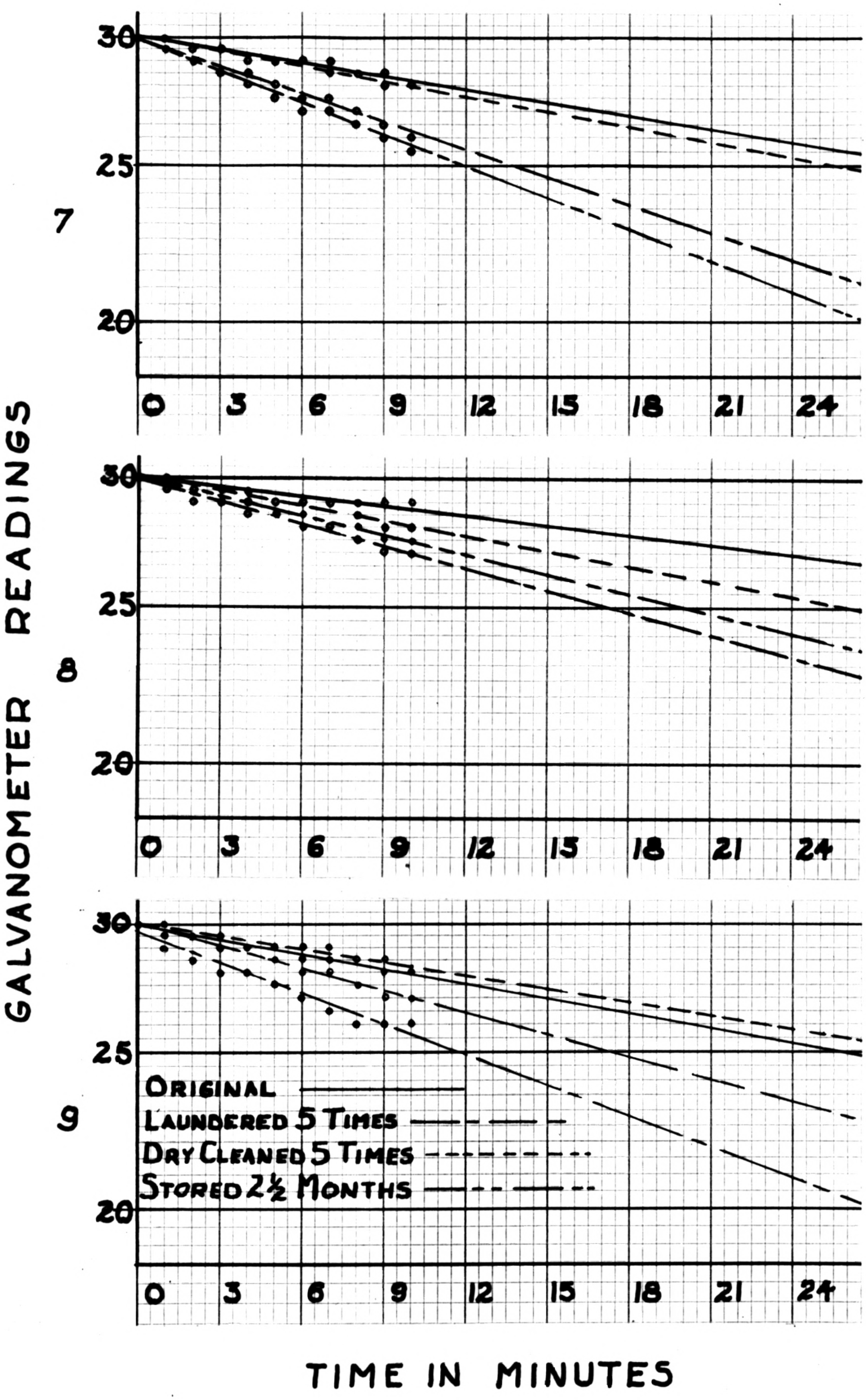

GALVANOMETER READINGS
4
5
6
30
25
20
0
3
6
9
12
15
18
21
24
ORIGINAL
LAUNDERED 5 TIMES
DRY CLEANED 5 TIMES
STORED 2½ MONTHS
TIME IN MINUTES

## EXPLANATION OF PLATE IV

Thermal conductivity graphs

7. Blanket 7 WC
8. Blanket 8 CR
9. Blanket 9 CR

# PLATE IV


GALVANOMETER READINGS
7
8
9
30
25
20
0 3 6 9 12 15 18 21 24
ORIGINAL
LAUNDERED 5 TIMES
DRY CLEANED 5 TIMES
STORED 2½ MONTHS
TIME IN MINUTES

for blankets in their original state. These data were also used to calculate the conductance of the original blankets and specimens of these blankets after laundering, dry cleaning, and storage.

Calculations for coefficient of heat transmission were made on the basis of equal thickness for all blankets in the original state (Table 5). A comparison of the blankets on this basis are shown in Fig. 1 where a long bar indicates high heat transmission and thus low protection. Blanket 3 W the heavy, thick wool, if it had been as thin as 1 W and 2 W would have given much less protection than either of these two blankets. Blanket 8 CR, a combination of cotton and rayon, resisted heat transmission the most and 7 WC showed similar resistance. Comparatively little difference was shown in this property of the other blankets. This indicates that the blankets tested containing all wool were no warmer than those of blends of rayon and cotton with wool and of cotton and rayon.

Calculations for conductance of blankets in the original state and after five launderings, five dry cleanings and two and one-half months of storage (Table 5) are shown in Fig. 2. Although no allowance is made for the variations in thickness of the blankets, the wool blankets held the same relationship in each other in the original state. Blanket 8 CR is again the warmest and 5 WRC is second. The blankets in order of resistance are 8 CR, 5 WRC, 7 WC, 4 WR, 1 W and 9 CR, 2 W, 3 W and 6 WC. This shows that of the blankets tested the three wool

Table 5. Thermal conductivity in terms of coefficient of heat transmission and conductance.

| Blanket | Coefficient of heat transmission | Conductance | | | |
|---|---|---|---|---|---|
| | Original state | Original state | Laundered 5 times | Dry cleaned 5 times | Stored 2½ months |
| 1 W | .136 | .247 | .180 | .190 | .322 |
| 2 W | .162 | .264 | .139 | .164 | .239 |
| 3 W | .290 | .290 | .167 | .088 | - |
| 4 WR | .175 | .224 | .154 | .176 | .211 |
| 5 WRC | .156 | .170 | .161 | .137 | .168 |
| 6 WC | .183 | .352 | .274 | .352 | .274 |
| 7 WC | .132 | .218 | .462 | .247 | .529 |
| 8 CR | .115 | .161 | .370 | .239 | .322 |
| 9 CR | .198 | .247 | .569 | .218 | .370 |

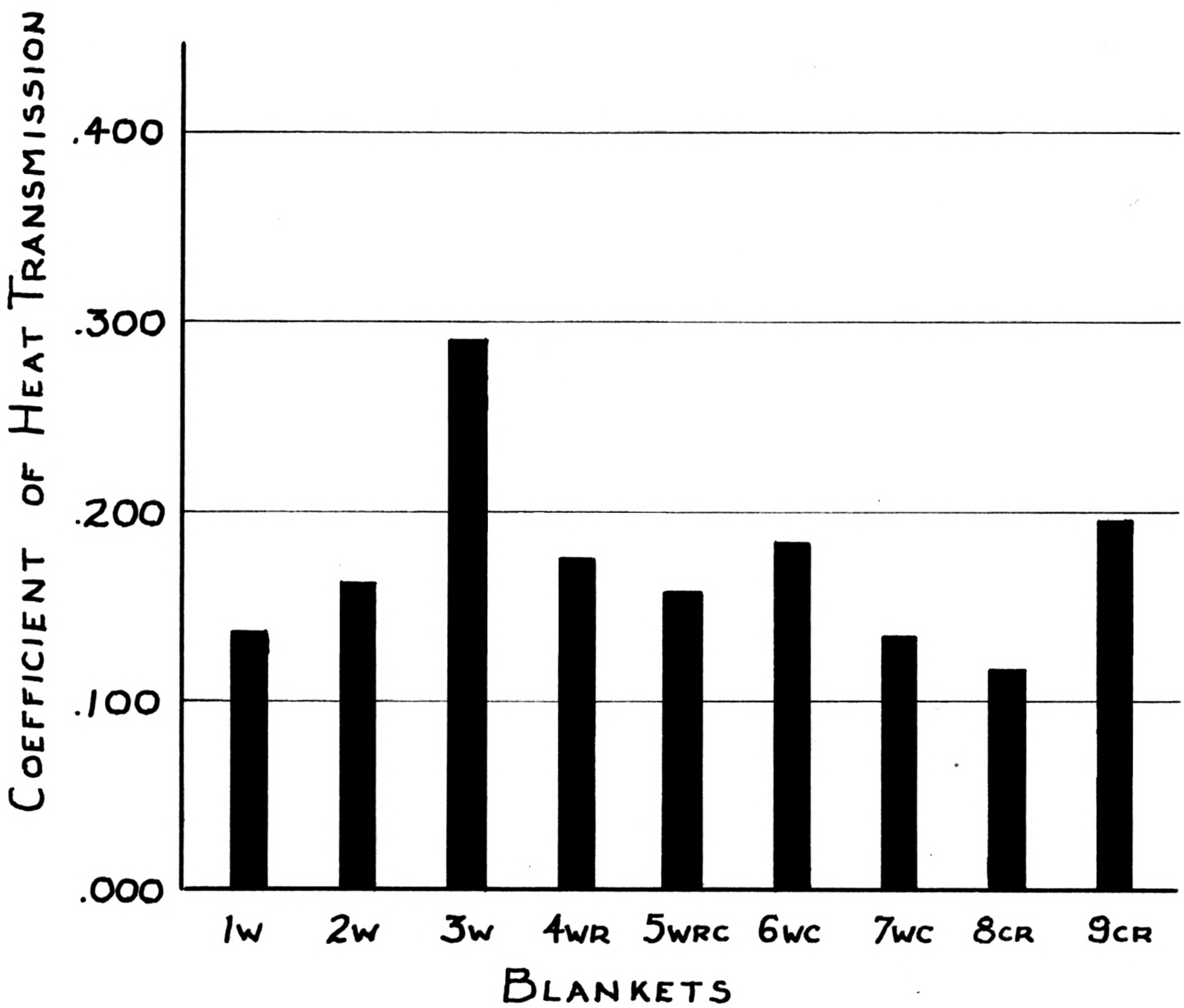



Fig. 1. A comparison of the coefficient of heat transmission of blankets in the original state on the basis of equal thickness.

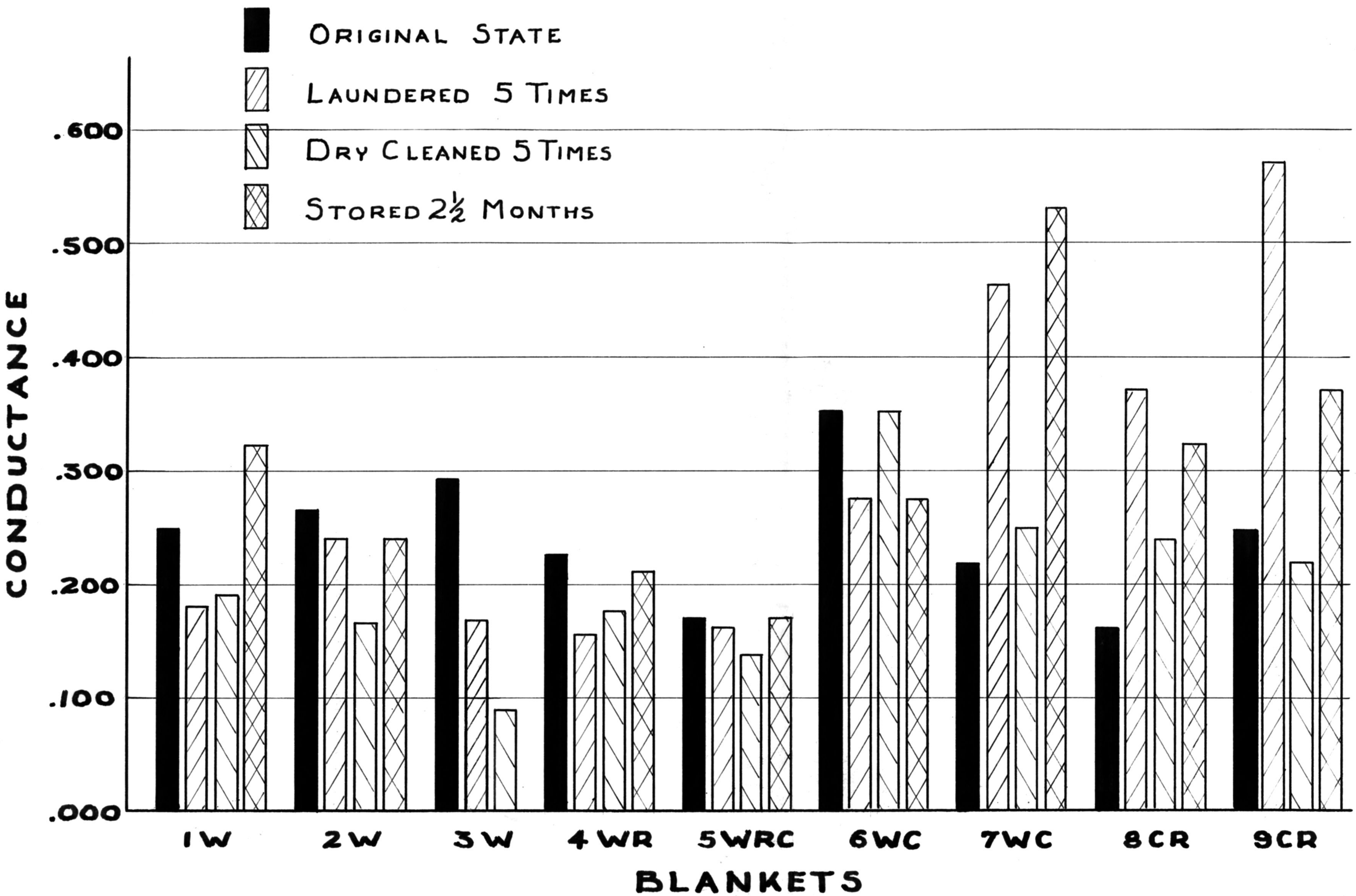



Fig. 2. A comparison of the effect of laundering, dry cleaning, and storage on the conductance of heat through the blankets. No allowance was made for the variation in the thickness of these blankets.

blankets in their original state were among the least resistant.

Laundered specimens of blankets (Fig. 2), 1 W, 2 W, 3 W, 4 WR, and 5 WRC, transmitted less heat than the originals. A comparison of 6 WC, containing 4.8 per cent wool, and 7 WC, containing 21.8 per cent wool, showed that the one containing a lower percentage of wool decreased in thermal conductivity after laundering and the one with the higher percentage of wool increased. The heat transmission of both of the cotton and rayon blankets, 8 CR and 9 CR, was increased after laundering.

Dry cleaned specimens of blankets 1 W, 2 W, 3 W, 4 WR, 5 WRC, and 9 CR showed a decrease in heat transmission. In blanket 6 WC the thermal transmission remained the same but was increased in 7 WC and 8 CR. Specimens of blankets 4 WR, 6 WC, 7 WC, 8 CR, and 9 CR (Fig. 2) showed less change in heat transmission after dry cleaning than after laundering.

## Resiliency

Results of resiliency tests are shown in Table 6. A comparison of blankets in the original state indicated that as a group, the all wool blankets, Nos. 1 W, 2 W, and 3 W were the more resilient. The blankets 4 WR and 5 WRC containing rayon were more resilient than the blankets of wool and cotton and of cotton and rayon. Laundering and dry cleaning reduced the resiliency of all the blankets except 2 W. Although

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storage reduced the thickness of all blankets, calculations as made would indicate that storage increased the resiliency of blankets 2 W, 7 WC, and 9 CR and decreased the resiliency of the other specimens.

## Shrinkage and Dimensional Restorability

Laundering as shown in Table 7 caused all blankets to shrink in the warp. The shrinkage varied from six to 16 per cent. Blankets 5 WRC and 9 CR shrank over 13 per cent and 4 WR shrank 16 per cent. The blankets, 1 W, 2 W, 3 W, 6 WC, 7 WC and 8 CR shrank from six to almost 10 per cent. The shrinkage was comparatively slight in the filling, varying from 0.1 to 2.8 per cent. The two cotton and rayon blankets, 8 CR and 9 CR, stretched 1.0 per cent and 2.5 per cent respectively. Restorability of the blankets after laundering was attempted. In Table 2 a four-pound weight was recommended to restore a fabric in which the shrinkage was five per cent and over. In blankets 1 W, 4 WR, 5 WRC, and 6 WC this weight failed to restore the blanket to within ± two per cent of the original length. The filling shrinkage was less than five per cent; hence, smaller weights were required for restorability. In every case the filling dimensions were restored to within ± two per cent of the original width.

Dry cleaning caused the blankets to shrink less in the warp than did laundering (Table 7); however, those that shrank most in laundering tended to shrink most in dry cleaning. Blankets 4 WR, 5 WRC, 7 WC, and 9 CR shrank 3.5, 3.8, 3.8 and 3.7 per cent, respectively, in the warp. The other blankets shrank from 0.4 to 1.7 per cent. In only one case, 5 WRC, was shrinkage in the filling enough to be noticeable in use. This blanket shrank 3.7 per cent and the others varied from -0.7 to 1.7 per cent.

Table 7. Percentage of shrinkage due to laundering and dry cleaning. Pounds required to restore laundered samples and restorability of nine selected blankets.

| Blanket | Laundered 5 times | | | | | | Dry cleaned 5 times | |
|---|---|---|---|---|---|---|---|---|
| | Per cent shrinkage | | Tension required to restore (lb.) | | Restorability | | Per cent shrinkage | |
| | Warp | Filling | Warp | Filling | Warp | Filling | Warp | Filling |
| 1 W | 8.0 | 2.8 | 4 | 1.0 | 2.2 | 0.8 | 0.8 | 0.5 |
| 2 W | 9.7 | 1.0 | 4 | 0.5 | 0.2 | 0.2 | 1.0 | 1.3 |
| 3 W* | 6.0 | 2.4 | | | | | 0.4 | 0.4 |
| 4 WR | 16.0 | 2.4 | 4 | 1.0 | 3.2 | 1.0 | 3.5 | 1.3 |
| 5 WRC | 13.3 | 0.7 | 4 | 0.5 | 2.3 | 1.6 | 3.8 | 3.7 |
| 6 WC | 8.6 | 2.0 | 4 | 1.0 | 3.0 | 1.2 | 1.7 | 1.7 |
| 7 WC | 7.2 | 0.1 | 4 | 1.5 | 0.2 | 0.0 | 3.8 | 0.1 |
| 8 CR | 8.0 | -1.0 | 4 | 0.5 | -0.2 | 0.0 | 1.7 | -0.9 |
| 9 CR | 13.7 | -2.5 | 4 | 0.5 | 1.8 | 0.7 | 3.7 | -0.3 |

* Not enough fabric available for restorability test.

## SUMMARY

The purpose of this study was to determine the effects of fiber content, laundering, dry cleaning, and storage on the thermal conductivity, and resiliency of certain selected blankets.

Under the conditions of these tests, 100 per cent wool fiber content had no more effect on the thermal transmission of the blankets in the original state than blends of other fibers. Blends of cotton and rayon, and of wool and rayon were as warm as the all-wool blankets. Thick blankets tended to be warmer than thin ones in the original state.

Laundering and dry cleaning seemed to increase the thickness and the resistance to heat flow of the all-wool blankets and blends of wool and rayon. Blankets containing cotton showed less change in thickness as a result of cleaning. Laundering reduced the ability of these blankets to resist heat flow, whereas dry cleaning changed them little in this respect.

Storage increased the thermal conductivity of one wool, one cotton and wool, and the cotton and rayon blankets. It decreased the thermal conductivity of one cotton blanket containing slightly less than five per cent wool and had no noticeable effect on the other blankets.

Wool blankets were found to be more resilient than blends

of other fibers. Laundering and dry cleaning tended to reduce the resiliency of the blankets. Although storage reduced the thickness of all the specimens, calculations as made indicated that storage increased the resiliency of one all-wool, one wool and cotton, and one cotton and rayon and decreased the resiliency of the other specimens.

Shrinkage resulted from both types of cleaning but dry cleaning caused less shrinkage than laundering. All blankets shrank in the warp. The all-wool blankets were among those with the lowest percentage of shrinkage. Five launderings resulted in warp shrinkage of six to 16 per cent, the highest percentage occurring in blankets containing rayon. Filling shrinkage due to laundering was not large enough to cause a great loss in the width of any of the blankets.

Five dry cleanings caused the fabrics to shrink in the warp from one-tenth to five-tenths as much as laundering. The highest percentage of shrinkage was 3.8, although this was enough to cause a noticeable loss in the length, it was small compared to the loss of 13.3 per cent in the same blanket laundered five times. The filling shrinkage was negligible.

The blankets containing cotton and rayon became harsh and lost their fluffiness after laundering, but dry cleaning did not affect them noticeably.

## ACKNOWLEDGMENT

Appreciation is expressed to Mrs. Katherine Hess, Associate Professor of Clothing and Textiles, for her guidance in directing this study.

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