

1964

# A Study of the Effectiveness of Shrink-resistant and Antibacterial Finishes on Wool Blankets After Repeated Launderings

Coila M. Janecek

Follow this and additional works at: <https://openprairie.sdstate.edu/etd>

---

## Recommended Citation

Janecek, Coila M., "A Study of the Effectiveness of Shrink-resistant and Antibacterial Finishes on Wool Blankets After Repeated Launderings" (1964). *Electronic Theses and Dissertations*. 2998.  
<https://openprairie.sdstate.edu/etd/2998>

This Thesis - Open Access is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact [michael.biondo@sdstate.edu](mailto:michael.biondo@sdstate.edu).

A STUDY OF THE EFFECTIVENESS OF SHRINK-RESISTANT  
AND ANTIBACTERIAL FINISHES ON WOOL BLANKETS  
AFTER REPEATED LAUNDERINGS

BY

COILA M. JANECEK

A thesis submitted  
in partial fulfillment of the requirements for the  
degree Master of Science, Major in Textiles  
and Clothing, South Dakota State  
College of Agriculture and  
Mechanic Arts

1964

SOUTH DAKOTA STATE UNIVERSITY LIBRARY

A STUDY OF THE EFFECTIVENESS OF SHRINK-RESISTANT  
AND ANTIBACTERIAL FINISHES ON WOOL BLANKETS  
AFTER REPEATED LAUNDRIES

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

\_\_\_\_\_  
Thesis Adviser

Dec 10 1964  
Date

\_\_\_\_\_  
Head of the Major Department

Jan 22 1964  
Date

## ACKNOWLEDGMENTS

The author wishes to express her sincere appreciation to Professor Lillian O. Lund and Dr. Edward C. Berry for their guidance and assistance throughout the course of the study reported here and the preparation of this thesis.

The author also wishes to express her thanks to her husband and children, whose many kindnesses made it possible for her to complete the work.

CMJ



## TABLE OF CONTENTS

	Page
INTRODUCTION . . . . .	1
REVIEW OF LITERATURE . . . . .	3
<u>The Wool Fiber</u> . . . . .	3
<u>Shrinkage of Wool</u> . . . . .	6
<u>Halogenation Treatments</u> . . . . .	8
<u>Oxidation Treatments</u> . . . . .	9
<u>Alkali Treatments</u> . . . . .	9
<u>Enzyme Treatments</u> . . . . .	9
<u>Resin Treatments</u> . . . . .	10
<u>Addition of Copolymers</u> . . . . .	10
<u>Antibacterial Finishes</u> . . . . .	14
METHODS OF PROCEDURE . . . . .	21
<u>Blanket Selection</u> . . . . .	21
<u>Sampling</u> . . . . .	21
<u>Laundry Method</u> . . . . .	22
<u>Laboratory Measurements of Physical Characteristics</u> . . . . .	23
<u>Fabric Structure</u> . . . . .	23
<u>Fabric Count</u> . . . . .	23
<u>Weight</u> . . . . .	24
<u>Thickness</u> . . . . .	24
<u>Dimensional Stability</u> . . . . .	24
<u>Appearance and Hand</u> . . . . .	25

	Page
<u>Antibacterial Finishes</u> . . . . .	25
<u>Blankets</u> . . . . .	25
<u>Preparation of Samples</u> . . . . .	26
<u>Sterilization Method</u> . . . . .	26
<u>Test Bacterium</u> . . . . .	27
<u>Test Procedures</u> . . . . .	27
<u>Practical Test</u> . . . . .	29
DATA AND DISCUSSION . . . . .	30
<u>Physical Properties</u> . . . . .	30
<u>Fabric Structure</u> . . . . .	30
<u>Fabric Count</u> . . . . .	30
<u>Weight</u> . . . . .	30
<u>Thickness</u> . . . . .	33
<u>Dimensional Change</u> . . . . .	33
<u>Appearance and Hand</u> . . . . .	36
<u>Antibacterial Properties</u> . . . . .	36
<u>Qualitative Test</u> . . . . .	36
<u>Quantitative Test</u> . . . . .	38
<u>Practical Test</u> . . . . .	38
SUMMARY . . . . .	44
CONCLUSIONS . . . . .	47
SUGGESTIONS FOR FURTHER STUDY . . . . .	48
LITERATURE CITED . . . . .	49
EXHIBIT A . . . . .	52

LIST OF TABLES

Table		Page
1.	Label Information and Physical Properties of Eight Wool Blankets Before Laundering and After 1, 5 and 10 Laundry Intervals . . . . .	31
2.	Dimensional Change and Area Shrinkage After 1, 5 and 10 Launderings . . . . .	37
3.	Bacterial Counts on Control Blanket and Blankets Treated with an Antibacterial Finish Before Laundering and After 1, 5 and 10 Laundry Intervals . . . . .	39

## LIST OF FIGURES

Figure	Page
I. Percent dimensional change in the warp (lengthwise) direction of eight blankets after laundering 1, 5 and 10 times . . . . .	34
II. Percent dimensional change in the filling (crosswise) direction of eight wool blankets after laundering 1, 5 and 10 times . . . . .	35
III. Bacterial counts using 1/100,000 dilution on wool blankets before laundering and after 1, 5 and 10 laundry intervals . . . . .	40
IV. Agar plates cultured 1/100,000 dilutions for wool control blanket (without finish) before laundering and after 1, 5 and 10 laundry intervals . . . . .	41
V. Agar plates cultured 1/100,000 dilution for blanket number 7 with antibacterial finish, before laundering and after 1, 5 and 10 laundry intervals . . . . .	42
VI. Agar plates cultured 1/100,000 dilution for blanket number 8 with antibacterial finish, before laundering and after 1, 5 and 10 laundry intervals . . . . .	43

## INTRODUCTION

Wool blankets are important to the economy of the state since South Dakota is one of ten leading states in wool production (20). However, the past years have seen the actual poundage of wool increase, but the percentage in relation to other fibers has gone down from 21 percent in 1890 to about 10 percent in 1959 (39). Wool's greatest competitor, synthetic fibers, has increased in production from 85.2 million pounds in 1949 to 470.5 million pounds in 1958 (21), an increase of approximately 550 percent. This competition by synthetic fibers has resulted in the wool industry undertaking intensive research to develop finishes that would improve the quality of wool products.

South Dakota and Minnesota Agricultural Experiment Stations began a cooperative research study in 1958 on wool, acrylic, wool-Orlon and rayon blends of blankets. Results of that study indicated that wool blankets ranked highest of all fiber types in warmth qualities (18), however, shrinkage in laundering was a limitation. Since completion of that study blankets treated to prevent shrinkage or dimensional change have become available on the market.

It was decided by workers at the South Dakota and Minnesota Agricultural Experiment Stations to continue research on blankets using all wool blankets with the new shrink-resistant finishes. An antibacterial treatment was also indicated on some of the labels. The application of this finish which was applied to retard bacterial

growth on blankets was new and little could be found in the literature reporting research in this area.

Blankets purchased for the study included two blankets labeled machine washable and six with shrink-resistant finishes, two of which had antibacterial treatments. Using these blankets, it was the purpose of this investigation to compare shrink-resistant finishes and their effectiveness on wool blankets after repeated launderings; and to determine effectiveness of antibacterial finishes on wool blankets after repeated launderings.

## REVIEW OF LITERATURE

The Wool Fiber

Wool has been spun into yarn and woven into fabrics since prehistoric times. Garments made of wool are held in high esteem and are universally worn. However, excellent as wool is as a textile fiber, it may present two serious problems: it is subject to biological attack by moths and carpet beetles; and it shrinks when laundered (30).

The problem of biological attack by insects has been solved to a large extent. Fabrics can be purchased that are treated to provide satisfactorily durable protection against moths even after repeated dry cleaning or laundering (14)(26).

When wool is viewed under a microscope it is readily identified by its scale structure. Moncrieff (30) uses in his description of wool a definition from J. Burnley that is over sixty years old but feels it is worth repeating today.

A hair has a smooth surface, comparatively free from jagged edges or serratures of any size, and lies straight, while the fibre of wool is more or less waved, and is covered with serratures. A fibre of wool may in fact be likened to a serpents' skin, or to a fir cone covered with scales. The serratures, or saw-like teeth, representing these scales, overlap each other and present innumerable little points which act as hooks. They are extremely small, and on the fibre there are said to be from 1200 to 3000 per inch.<sup>1</sup>

---

<sup>1</sup>R. W. Moncrieff, Wool Shrinkage and its Prevention (New York, 1954), p. 9.

The scale structure gives wool its characteristic warmth and softness of handle. At the same time it is also responsible for wool's ability to shrink and felt (30).

There are three morphological components in the wool fiber: the cuticle or outside of the fiber which is made up of flat irregular horny cells or scales; inside the cuticle is the cortex which is composed of millions of small spindles called cortical cells; and in coarse wool one often finds a medulla which consists of a network of hollow, air filled cell walls (40). According to Von Bergen (40) wool fiber is an organized structure growing from a root situated in the dermis or middle layer of skin. It is similar in origin to a number of other epidermal skin tissues such as hair, horn, nails and feathers.

Wool possesses certain characteristics which distinguishes it from all other fibers. The fiber has a natural crimp which varies from practically no crimp at all to as many as 22 to 30 crimps per inch (14). More crimps per inch is usually an indication of finer wool (22) and has an important bearing on the properties of the resultant textile products (14). Another of these characteristics is resilience which is the springiness of a fiber mass or the ability of a fiber to return to its original volume after being compressed (22). Hopkins (14) says that resilience gives wool its loft which produces open, porous fabrics of high covering power and thick warm fabrics with a minimum of weight.



According to Matthews (22) the wool fiber is composed of animal tissues and is classified as a protein called keratin. Chemically, the wool fiber is composed of five elements: carbon, hydrogen, oxygen, nitrogen and sulfur. Sulfur is distinctly characteristic of wool and of all hair fibers. However, as wool's constituents are not rigidly constant in their proportion, no definite chemical formula can be assigned to wool.

Moncrieff (30) states that the protein keratin is of amphoteric nature exhibiting acid as well as basic properties with the basic characteristics in predominance. Through hydrolysis keratin decomposes into at least eighteen different amino acids which have widely differing side chains. Some degree of molecular irregularity is a characteristic of wool and it is not a highly crystallized or highly oriented fiber. This results in wool not being a strong fiber but having considerable extensibility and being soft and pliable.

The wool molecule contains many intensely reactive groups, particularly the free amino and free carboxylic groups which give the fiber a high degree of chemical reactivity and an ease of dyeing (30).

The cystine cross-linkages increase both the mechanical and chemical stability of the fiber. It has been shown that many of the physical, chemical and biological properties of wool protein are dependent on the presence of these cross links (22). Wool may thus be considered a network of polypeptide chains linked together by the disulphide groups of amino acid cystine and salt linkages. The salt

linkages insure stability of the wool fiber in solutions which are nearly neutral or in any aqueous media which lies between the range of pH 4 to 8 (30).

The warmth and softness of handle in fibers are associated with a reasonable high moisture absorption, with pliability, with high extension and low tenacity. These properties are associated with a low degree of orientation which is a characteristic of wool and most other protein fibers (30).

#### Shrinkage of Wool

Wool has the distinction of being unsurpassed in outstanding textile qualities; however, it has one serious limitation, the tendency to shrink when laundered. This shrinkage can be divided into three types: relaxation, felting and consolidation (38).

Steiger (38) says that the reason for relaxation shrinkage is that yarns are placed under tension during the weaving and finishing processes and do not return to normal until moisture is applied. When the fabric is placed in water or perhaps only steamed, pressed or sponged, latent strains are released and the fibers return to their original length. The extent of relaxation shrinkage is dependent to a large extent on those who control the mechanical processes to which wool is subjected (38). London shrinking and steaming operations can be employed to reduce relaxation shrinkage (22).

Felting shrinkage, which is the matting together of the fibers, occurs when wool is exposed to heat, moisture and mechanical action (2).

One of the more common theories as to the cause of felting shrinkage is that it results from the movement of the fibers within the yarn or fabric (15)(30). Scales on the fiber point toward the tip and considerable more friction exists when the fiber is pulled from the tip to root than from root to tip. The friction which takes place when the fiber is pulled in the tip direction is referred to as directional frictional effect (D. F. E.) (30).

According to Steiger (38) the three fiber qualities necessary to produce felting have been designated as (a) unique surface structure, (b) ability to stretch, and (c) power to recover from stretching. When a wool fabric is subjected to repeated stresses, as in laundering, the elastic motions together with the directional friction effect cause the fibers to migrate rootward, carrying other fibers with which they have become entangled. With repeated launderings the wool fibers continue to become so entangled that they cannot be separated in a practical manner without considerable fiber damage. This is felting.

Another type of shrinkage known as consolidation may take place. In some instances manufacturing strains are not completely removed by the standard hot water or steam relaxation treatments and mechanical action is necessary to speed the relaxation process. If the fabrics are not fully relaxed when laundered, they may shrink even though no fiber migration or felting shrinkage takes place (30)(38).

The principles underlying the various shrink-resistant finishes are based on reduced frictional effect, altered elastic properties or both. The differential friction effect can be reduced by removing the

scales, modifying the surface or masking the scales (30)(38). The elastic properties may be altered by such treatments as crosslinking, internal polymer deposition or chemical modification. Some shrink-resistant finishes give the apparent effect of modifying the elastic properties of the fibers by immobilizing them in the fabric structure. This effect has been called "spot welding" or fiber bonding (19)(38).

Many shrink-resistant treatments are available for wool as may be indicated by the 250 patents that had been issued on the subject prior to 1957 (38). The major processes may be classified under one of the following treatments: halogenation, oxidation, alkali, enzyme, resin and addition of copolymers (37)(38).

#### Halogenation Treatments

The treatments which have received and continue to receive wide support for making wool shrink-resistant are those which use chlorine or other halogens so as to alter the directional friction effect of the wool fiber (10)(37). In their simplest forms, the chlorination treatments are low in cost and are reasonably effective (38). There is a tendency to consider all such processes and their effects on the properties of wool as being similar, whereas, in practice, they differ widely in the degree of shrink-resistance obtained and in the extent to which they alter the properties of the fiber (10). The ideal chlorinating solution includes a buffer and must be balanced to the extent that it does its work quickly and affects only the fibers' scaly surface. If the chlorination treatment is done properly, the hand, color and dyeing properties of the fiber will be retained (15).

### Oxidation Treatments

With the oxidative treatments as with halogenations, the problem is the balance between effective shrink-resistance and keeping damage to the fiber at a minimum (30)(37). Some of the oxidizing agents have an advantage in that they are effective bleaching agents for wool but they are expensive in comparison to the cheaper forms of chlorine (37). The oxidant potassium permanganate is the basis for two of the processes that are being used on a large scale (13).

### Alkali Treatments

Numerous attempts have been made to alter the surface of the wool fiber and reduce its tendency to felt by treating it with either sodium or potassium hydroxide dissolved in various alcohols or combinations of "dry" solvents. Because of the need for solvent recovery and special machinery, these treatments are at a cost disadvantage when compared to the simpler chlorinations (30)(37).

### Enzyme Treatments

The enzyme papain is sometimes used to control shrinkage. A pretreatment with peroxide, dry chlorine, or other reagents is required to be effective, and this, together with the cost of papain, makes the treatment relatively expensive. However, the enzyme treatments have been used on a commercial scale both for making shrink-resistant wool and for making completely descaled fiber with a high, silklike luster (37).

### Resin Treatments

Resin finishes also provide effective shrink resistance. This is achieved by the formation of a thin, uniform resin film on the fiber surfaces and is applied by a technique known as interfacial polymerization (9). This treatment is based in part on the principle of masking the scales and partly by spot welding (37).

Melamine-formaldehyde resin treatments increase the fabric weight and generally improve fabric properties such as tensile strength, abrasion and pilling resistance (9). There is only small effect on dyes. A serious drawback is the loss of wool-like hand due to fiber bonding (38). The treatment is not recommended for heavier blanket fabrics (33).

### Addition of Copolymers

The use of acrylic polymers as shrink-resistant agents for wool compare favorably with other available treatments with regard to their ability to stabilize wool. They also have been found to be superior in minimizing pilling and fuzzing formation in laundered wool (19)(38).

In the United States several of the commercialized patented processes which are used on a large scale to produce shrink-resistant wool are Dylanize, WB-7 and the Wurlan process.

Dylanize is a well established treatment developed by Stevenson's Ltd., England (35). It is basically an oxidation process which employs a dilute solution containing both sodium hypochlorite

and potassium permanganate (13). This process is the one most often used to produce the shrink-resistant finish on wool blankets.

Russon (35) reports that the WB-7 process was developed jointly by C.S.I.R.O. (Commonwealth Scientific and Industrial Research Organization, Australia) and The Wool Bureau, Lowell, Massachusetts. This process is based on the treatment of wool with potassium permanganate in a concentrated sodium sulfate solution followed by clearing with sodium bisulfite. The WB-7 process is used to produce a wide variety of machine-wash-and-dry 100 percent wool garments, fabrics and blankets.

The Wurlan treatment has been developed by the United States Department of Agriculture's Western Regional Research Laboratory. Lundgren (19) describes the process as being relatively simple and involves immersion of wool successively in a diamine solution and a diacid chloride solution to form a very thin resin film through interfacial polymerization. The treatment has only minor effect on physical and chemical properties. The treated fabric shows excellent shrinkage control and dye washfastness (8)(33).

Throughout the world a number of different shrink-resistant processes are being used. One reason for this is that some processes are more suitable for some wool materials than for others. Another reason is that wool finishers are not in complete agreement as to which is the best process. With each process there are advantages and disadvantages (12).

According to Hall (13) it has been the experience of firms carrying out shrink-resistant treatments on wool that there are times

when exceptional results are obtained which cannot be accounted for. Occasionally the shrink-resistant results will be below that normally expected although no variation of the processing conditions can be traced. Research has indicated that there is a need to investigate further the exact nature of the wool wax component. It is thought that ways should be devised for eliminating it from the wool or of otherwise neutralizing its harmful effect on a shrink-resistant treatment.

Lundgren (19) reports that at the present time research in wool is aimed toward wider and greater consumer appeal and satisfaction. The consumers of today are asking for garments with better dimensional stability, greater resistance to mussiness, fuzziness and pilling, and quicker drying fabrics. Consumers also want softer, lighter-weight fabrics in lighter shades and new textures.

The Australian Wool Bureau has made much progress in shrink-resistant finishes. Several years ago a series of articles in medical journals condemned wool blankets. It was believed that the blankets produced fluff which spread infection, shrank rapidly if laundered and were damaged if heated to a temperature that would destroy staphylococci. The Royal Melbourne Hospital Group Laundry did not accept the claims and asked the C.S.I.R.O. to investigate the problem (34).

The research conducted by the C.S.I.R.O. indicated that an all wool blanket is preferable to other fibers; blankets should be laundered more frequently than has been the custom; fibers shed from wool



blankets seldom carry pathogenic bacteria; a shrink-resistant treatment should be applied to all blankets; sterilization of blankets may be done by boiling providing a suitable detergent (essentially non-alkaline) is used; and boiling causes no greater shrinkage, fabric deterioration or loss of tensile strength than the low temperature method of laundering (31).

McPhee (28) reports that the Australian Army has accepted the C.S.I.R.O. process for boiling all wool blankets and also the laundering and shrinkproofing processes for all types of wool clothing. It is estimated that these treatments increase the life of wool blankets at least 10 times—from about 15 launderings to more than 150.

The success that the Australian C.S.I.R.O. has had with blankets is also apparent on other wool fabrics. Dr. John R. MCPhee (26) has made the statement that "all the 'easy-care' features of fabrics made from synthetic fibres, blends of natural and synthetic fibres or other treated natural fibres, can now be produced industrially in 100 percent wool fabrics."<sup>2</sup> These processes are simple but they do add a small extra cost to the fabric (26).

McPhee (27) has found when testing shrink-resistant wool it is important to define washing conditions. Varied results can be obtained by washing in different machines and thereby applying different

---

<sup>2</sup> John R. MCPhee, "New Advances in Methods for Imparting Easy Care Properties to Wool Fabrics," Canadian Textile Journal 79:43-47. January 5, 1962.

mechanical forces to the fabrics. A treated fabric of loose structure, when washed for a given time in two different machines, can appear to be either completely shrink-resistant or scarcely shrink-resistant at all. The Wool Bureau has recommended that manufacturers sew permanent laundering and drying instructions for the consumer in all garments wherever this is possible (35).

#### Antibacterial Finishes

There has been increased interest in the application of treatments on fabrics which will impart resistance to the growth of bacteria and fungi (4). Industry and agriculture have been aware for some time of microbiological damage and are constantly devising ways to prevent it. Industry saves millions of dollars annually through the wise use of chemical and microbiological procedures. Food processing plants are treating their boxes and baskets to prolong their use. Nearly every phase of industry benefits from the advances which have been made in the science of microbiology (16).

Kramer (16) reports that in the last several years the consumer has had opportunities to read in daily newspapers and magazines about the dangers of bacterial infection, even in hospitals, and the importance of protection against them. As a result the public is becoming aware of the problem and beginning to demand more safeguards against these harmful bacteria.

The main objectives for the use of antibacterial finishes are: to control the spread of disease; to control development of odor from

perspiration and other soil on garments and fibrous structures; and to help control deterioration. Mildewproofing and rot-resistant treatments to control deterioration on out-of-door textiles such as tenting, awnings and outdoor furniture are the oldest of the antibacterial finishes (4)(36).

McNeil (24) states that antibacterial finishes are based on the following principles: (1) the fact that textile fibers can adsorb some disinfectants; and (2) that, in the presence of moisture, the fibers release the disinfectant in amounts sufficient to kill at least some of the bacteria.

There is a tendency to think of these treatments as being a modern innovation, but Egyptians applied the principle 4000 years ago in the use of certain spices and herbs for the preservation of fine fabrics in which mummies were wrapped (4). Cedar oil was a favorite preservative during Roman times. As early as 1900 cloth was treated to protect it from rot caused by microorganisms (24).

During World War II the German Army treated soldiers' uniforms with quaternary ammonium compounds and observed fewer secondary infections following combat wounds and injuries than did those whose uniforms were not treated (4)(24).

From the early 1950's to the present, much attention has been given to the danger of infection with drug resistant strains of bacteria, especially staphylococcus. This has had an influence on the current emphasis on improvement of environmental sanitation. This

program includes the treatment of textile materials and other surfaces with products intended to impart a self-sanitizing activity. Such products which are said to be effective include: quaternary ammonium compounds, bromo- and tetrachloro-salicylanilide, tri-chlorocarbanilide, organotin compounds, neomycin sulfate, phenyl mercuric acetate and borate, hexachlorophene and other phenolic disinfectants (24).

Requirements for such a finish are: it must be effective against many kinds of bacteria and fungi; there be no damage to the fabric nor loss of strength, hand and color characteristics; it does not possess an offensive odor nor be toxic to the finisher or user; it be long lasting as well as durable to the proposed care; and that it be economical in cost and application (6)(16)(36).

Some of the textile items on which it is desirable to have an antibacterial finish include: foundation garments, undergarments, outer garments, hosiery, bed linens, blankets, bed spreads, mattress covers, mattress stuffings, upholstery fabrics, carpets and rugs, carpet paddings, towels, wash cloths, handkerchiefs, sanitary napkins, table linens, bandages, military clothing, sporting and camping equipment, lining fabrics and toys (6)(11)(16)(24). In all of the items, the claims indicate resistance to the growth of pathogenic organisms and to microorganisms causing odor (4).

Control of ammonia dermatitis of babies and bed-ridden patients has been accomplished by impregnating diapers and dressings with a quaternary compound. This treatment is described as having the

appropriate bactericidal action on the urea splitting organisms and is available for hospital or home use (5)(24)(32).

Mention has been made of the work done by the Australian C.S.I.R.O. on wool blankets. In recent years this organization has spent much time and money tracking down the causes of cross-infection in hospitals. The wool blanket had been implicated as the source of the cross-infection. The research was conducted by Mr. T. A. Pressley, Principal Research Officer, C.S.I.R.O., Dr. Bryan Stratford, Deputy Medical Superintendent of St. Vincent's Hospital, Melbourne, and Professor S. D. Rubbo, Department of Bacteriology, University of Melbourne (17).

A bright yellow harmless marker organism, Staphylococcus citreus, was used to trace bacterial cross-infection in the hospital wards. The ward experiments revealed that when a 100 percent wool blanket was used without a bedspread, the quantitative spread of bacteria from it was least of all. The results indicated that pure wool blankets hamper rather than facilitate cross-infection. It was suggested that bedspreads should not be used on hospital beds and an attractive wool blanket used in its place (17).

As interest increased in antibacterial treated fabrics, it became apparent that laboratory methods to evaluate the finishes were needed. In 1953 an AATCC (American Association of Textile Chemists and Colorists) Research Committee consisting of nine members was formed. It was known as the Committee on Antimicrobial Agents. In

1956 the name was changed to the Committee on Antibacterial Agents. At present there are 27 members on the committee which indicates the continuing interest in the subject (24).

Evaluation of antibacterial finishes on fabrics necessitates consideration of the degree of the antibacterial activity intended in the use of the fabric. If only bacteriostatic activity (inhibition of multiplication) is intended, a qualitative procedure is sufficient. This clearly demonstrates antibacterial activity as contrasted with lack of such activity by an untreated sample. A number of chemicals are used as antibacterial agents, consequently several qualitative procedures need to be available (25). However, if bactericidal (disinfectant) activity is intended or implied, quantitative evaluation is necessary. The result of quantitative evaluation is more valid for suggesting uses of a treated fabric (25).

The AATCC Committee on Antibacterial Agents has concluded that it would be realistic to recommend acceptance of a two-part procedure as follows: (1) qualitative or presumptive tests, and (2) a quantitative or confirmatory test (25).

The qualitative test, which is a screening or presumptive test, could be used by testing laboratories, or research and development laboratories, to determine samples which show promise of antibacterial activity and which should be tested quantitatively (25).

The AATCC (1) has tentatively approved several qualitative tests. The Agar Plate Method (AATCC 90-1958) is dependent on the

production of a clear zone of inhibition around the treated fabric. An untreated control fabric must be included in the test. This procedure may be used to demonstrate bacteriostatic activity against Staphylococcus aureus.

The Streak Test (1)(25) is a modification of the Agar Plate Method. Agar plates are streaked with the test organism. Treated and untreated swatches are placed on the surface of the plate at right angles to the line of streak. Clear areas of no growth indicate presence of an antibacterial finish.

Major's Test (1)(25) is a semi-quantitative test procedure which involves changes in pH when the inoculum is suspended in a highly buffered medium.

The Quinn Test (1)(25) is a suitable method for bacteriostatic evaluation. It is an attempt to relate a test procedure to in-use conditions. Treated and untreated swatches are inoculated with the test organism and dried under controlled conditions. They are then placed on sterile agar plates, covered with a thin layer of agar and incubated. After incubation the number of colonies are counted under the low power lens of a microscope.

The quantitative test or confirmatory test which is recognized by the Antibacterial Committee is 100-1961T (1). This method was used for evaluation of the antibacterial finishes in this study and will be explained in the methods of procedure.

Gagliardi (11) reports that in examining the performance of new antibacterial agents combined with conventional textile finishing agents, it has been noted in research laboratories that many control samples without any bacteriostatic or bacteriocidal agents present, produced bacterial inhibition. These observations indicate that many of the finished fabrics leaving the textile plants today have initial antibacterial activity even though an antibacterial finish was not applied.

The progress of durable antibacterial finishes for textile materials will depend largely on new research which is needed to learn more about the mechanism of antibacterial action on specific bacteria encountered in textile uses (11).



## METHODS OF PROCEDURE

In the introduction two study objectives were indicated. The first was to compare shrink resistant finishes and their effectiveness on wool blankets after repeated launderings. The second was to determine effectiveness of antibacterial finishes on wool blankets after repeated launderings. These objectives are being considered separately in dealing with methods of procedure and data.

### Blanket Selection

Eight blankets were selected for this study, six of which had labels indicating a shrink-resistant finish had been applied. Two blankets were labeled machine washable but no mention of a special shrink-resistant finish was included. Labels also indicated that all were mothproof and two had an antibacterial finish. The blankets had nylon bindings, either satin or taffeta. Purchasing of the blankets was done at department stores and through mail order catalogues in 1962. The prices ranged from 12 to 20 dollars. Swatches of the blankets are shown in Exhibit A of the appendix.

### Sampling

Each blanket was cut into four parts and the raw edges finished with a zig-zag stitch on an automatic sewing machine. One section was put aside for laboratory analysis; the others were randomly withdrawn for analyses after one, five and ten washings. Original labels were removed and mounted in file folders for reference. White muslin labels

(approximately 2" x 3") for identifying the blankets and tabulating treatments were applied to each blanket section.

After the laundering intervals were completed and dimensional stability measurements taken, the blanket sections were used for measuring other properties. Samples were cut from different areas of the blanket to assure dissimilar warp and filling yarns. No samples were cut beyond a 6 inch margin of either the ends or selvages.

#### Laundry Method

All blankets were laundered in an automatic home style washer using the slow setting on a two-speed machine. A load consisted of four blanket sections, randomly selected. The water was softened with a commercial installation of the ion exchange type and hardness was checked prior to each laundering. Water temperature of 80 degrees Fahrenheit, plus or minus 2 degrees, was used for both washing and rinsing. A soap solution was prepared in advance by dissolving one-fourth pound of neutral soap chips (Federal Specifications PW 566b) in 1 quart hot water.

The machine was filled with water of the proper temperature. A setting of normal action on the machine was used to dissolve 1 cup of soap solution. The machine was then reset at slow action; blanket sections were added and agitated for two minutes. After the water extraction and spin, the blankets were removed. The machine was filled with rinse water in which the blankets were agitated one and one-half minutes. The water extraction and spin completed the washing operation.

The blankets were dried in an electric dryer. Bath towels were preheated and layered between the four sections of blanket. The towels absorbed moisture and helped cushion the tumbling action of the dryer. As soon as the binding no longer felt damp (10 to 15 minutes), the blankets were removed, shaken and placed over lines to finish drying.

### Laboratory Measurements of Physical Characteristics

Procedures for the measurements of these properties were standard methods of the American Association of Textile Chemists and Colorists (1) and American Society for Testing Materials (3). Fabric structure, thread count and dimensional stability were measured at ordinary room conditions. Weight and thickness measurements were conducted under standard atmospheric conditions (65 percent relative humidity and 70 degrees Fahrenheit, plus or minus 2 percent and 2 degrees, respectively).

#### Fabric Structure

The fabric structure was analyzed by describing the type of weave, indicating direction of twill.

#### Fabric Count

Fabric count was made on the weight samples in both warp and filling directions. The counts were done before laundering and after 1, 5 and 10 laundry intervals. A micrometer counter was used for most of the counts. On a few of the heavily napped samples it was necessary

to ravel out several threads and clip so as to leave one inch of threads which could be counted. The results were averaged and carried to two decimals and rounded to one.

#### Weight

Two specimens exactly 2 x 2 inches were cut with a steel rule die on an Alfa cutter made by Thwing Albert Company of Philadelphia, Pennsylvania, from each quarter section of blanket before laundering and after 1, 5 and 10 laundry intervals. The samples were weighed on a 5 gram capacity Roller-Smith precision balance to the nearest 0.001 of a gram. The mean value for the two samples was converted to ounces per square yard and recorded as the fabric weight.

#### Thickness

A compressometer which reads directly to the nearest 0.001 inch, equipped with a presser foot one inch in diameter was used. Thickness was measured at the center of each weight sample before laundering and after 1, 5 and 10 laundry intervals. The foot was lowered to apply a load of 0.50 pounds per square inch and allowed to rest 10 seconds before the reading was taken. The average of the results was reported as thickness of the fabric.

#### Dimensional Stability

A quarter of the blanket was laid without tension on a flat hard surface. Three distances each of 18 inches were marked in both the warp and filling directions by a hand stitch. The dimensional change

was determined after 1, 5 and 10 launderings. The three distances previously marked were measured in both warp and filling directions using a steel yard stick measuring to the nearest one thirty-second of an inch and converted to the nearest one-hundredth inch. The same measurement was taken using a Cluett Peabody Shrink Tape which records in percent.

#### Appearance and Hand

A group of seven Home Economics faculty members were asked to evaluate and make comparisons of the blankets on appearance and hand after the blankets had been laundered 1, 5 and 10 times.

#### Antibacterial Finishes

##### Blankets

The label of one blanket mentioned that both the blanket and binding were hygienically clean and permanently bacteria resistant. The other blanket was labeled to the effect that a permanent antiseptic treatment had been applied which would last through many launderings. In this study these blankets will be referred to as number 7 and number 8 respectively. The blanket used as a control was all wool and had similar construction but no special treatment had been applied to it. For negative control which is a check on the procedure, the treated and untreated blankets were used but were not inoculated.

### Preparation of Samples

Samples were cut using a 1 1/8" circular steel die on an Alfa cutter made by Thwing Albert of Philadelphia, Pennsylvania. Duplicate samples were cut for the 0, 1, 5 and 10 treatments of the test blankets and the control blanket. One additional sample of each blanket was cut for negative control. Each sample was placed in a dilution bottle and then capped with a rubber stopper. The dilution bottles were used in place of the wide-mouth glass jars suggested in the manual (1) so that the bottles could be placed on an automatic shaking device.

A cam reciprocating shaker manufactured by the A. S. Aloe Company of St. Louis, Missouri, was used. The shaker was designed so that the bottles could be anchored securely and the rate of speed was 200 vibrations of the cam per minute. This method was used to help detach the bacteria which tended to cling to the scaly surface of the wool fiber.

### Sterilization Method

In considering methods for sterilization it was of importance to select a method that did not damage the fiber or the finish (25). An American all purpose Junior Autoclave manufactured by the American Sterilizer Company of Erie, Pennsylvania, was used. The bottles containing the blanket samples were arranged in the autoclave on the rack in an inverted position so as to avoid moisture collecting in the bottles. The rubber stopper was placed close to the bottle and

inserted as soon as the exposure period had terminated. The samples were exposed to 220 degrees Fahrenheit for 30 minutes.

Ethylene oxide gas (23) was attempted as a method of sterilization but was not successful. It was apparent that a toxicant remained on the blanket samples and prevented growth of Staphylococcus aureus.

### Test Bacterium

Staphylococcus aureus, strain 209 was used throughout the tests as the inoculum.

### Test Procedures

The AATCC Committee on Antibacterial Agents (RA-31) has recommended a two-part procedure (Tentative Test Method 100-1961T) consisting of a qualitative and a quantitative test (1).

1. Qualitative Test. The qualitative test selected was the AATCC Agar Plate Method (1). One adaptation was made to the procedure. The blanket swatch was first dipped into sterile AATCC Bacteriostasis broth (1) which dampened the surface of the blanket and permitted it to absorb the tryptone glucose extract agar (7). The agar had previously been seeded with Staphylococcus aureus, 1 milliliter of inoculum to 100 milliliters of agar. The inoculum was prepared by adding 1 loop (1/20th milliliter) of culture to 10 milliliters of sterile Bacteriostasis broth and incubated at 37 degrees centigrade for 24 hours. Qualitative tests were carried further using a dilution of 1 milliliter of inoculum to 10 milliliters of broth. Dilutions of one to one

thousand and one to one hundred thousand were made following the regular dilution procedure.

After incubation of 37 degrees centigrade for 24 hours, a clear zone of no growth adjacent to the specimen indicates antibacterial activity of the fabric (1).

2. Quantitative Test. The inoculum was prepared by adding 1 loop (1/20th milliliter) of culture to 10 milliliters of sterile Bacteriostasis broth and incubated at 37 degrees centigrade for 24 hours. A dilution was made by transferring 1 milliliter of the inoculum into 99 milliliters of broth. This dilution was mixed well and using a pipette, 1 milliliter was carefully added onto each blanket sample that was to be inoculated. Samples were incubated at 37 degrees centigrade for 24 hours. After incubation 100 milliliters of sterile Bacto-Peptone (7) was added to the inoculated samples. One hundred milliliters of sterile Bacto-Peptone was also added to the uninoculated blanket samples which served as a negative control. The bottles containing the blanket samples and Bacto-Peptone were agitated on a reciprocating shaker for 30 minutes. Immediately after the shaking process 1 milliliter of the inoculated sample was transferred to a sterile 99 milliliter Bacto-Peptone blank, making a dilution of one to one hundred. Dilutions of one to ten thousand, one to one million and one to one hundred million were prepared using Bacto-Peptone and following the regular dilution procedure. All dilutions except one to one hundred were plated in duplicate in tryptone glucose extract agar.



The uninoculated blanket samples were plated in tryptone glucose extract agar using 1 milliliter of the Bacto-Peptone wash.

The plates were incubated at a temperature of 37 degrees centigrade for 48 hours after which they were counted on a Quebec colony counter. The number of bacteria per milliliter was calculated by multiplying the number of colonies by the dilution.

#### Practical Test

In order to further study the effectiveness of antibacterial finishes, swatches of the treated and untreated blankets were cut and not sterilized. The prepared samples were left uncovered in the laboratory for a day before plating. The following day the samples were dipped in sterile broth and cultured in tryptone glucose extract agar. The plates were incubated at a temperature of 37 degrees centigrade for 48 hours after which the bacterial growth was observed.

## DATA AND DISCUSSION

Discussion of the data collected in this study is divided into two sections. The first section includes information pertaining to physical characteristics of the blankets and results of dimensional stability. The second section deals with antibacterial finishes.

To simplify the discussion of data, the blankets will be referred to by number (Table 1).

### Physical Properties

#### Fabric Structure

The weave structure was not apparent on six of the blankets because of the napping. Examination under a microscope revealed that four blankets 2, 5, 6 and 8 had a twill weave. Blankets 1, 3, 4 and 7 had a modified plain or basket weave.

#### Fabric Count

The number of threads per inch was approximately the same for all blankets except number 5, which had about ten more threads per inch in each direction. After one laundering the thread counts for all blankets increased slightly in both warp and filling directions, no doubt due to the relaxation shrinkage (Table 1).

#### Weight

During the first laundering the relaxation shrinkage caused the threads to become closer together and this resulted in an increase of

Table 1. Label Information and Physical Properties of Eight Wool Blankets Before Laundering and After 1, 5 and 10 Laundry Intervals

Blanket number	Label information	Times laundered	Fabric count		Weight	Thickness
			Threads per inch Warp	Threads per inch Filling	Ounces per square yard	inches
1	Washable Mothproof	0	20	23	10.1	0.126
		1	22	25	10.0	0.137
		5	20	25	11.1	0.146
		10	21	26	10.9	0.147
2	Washable Mothproof	0	25	29	11.6	0.150
		1	26	30	12.5	0.166
		5	27	32	13.0	0.164
		10	26	32	13.1	0.160
3	Shrink-resistant Mothproof	0	22	28	10.5	0.125
		1	25	28	12.3	0.148
		5	24	28	12.0	0.146
		10	24	30	11.5	0.139
4	Shrink-resistant Mothproof	0	24	26	11.1	0.148
		1	24	27	12.0	0.148
		5	23	28	11.2	0.142
		10	23	28	11.3	0.146
5	Shrink-resistant Mothproof	0	34	36	11.4	0.122
		1	35	38	12.5	0.133
		5	34	38	12.4	0.131
		10	34	38	12.0	0.129

Table 1. (continued)

Blanket number	Label information	Times laundered	Fabric count		Weight Ounces per square yard	Thickness inches
			Threads per inch Warp	Threads per inch Filling		
6	Shrink-resistant	0	24	24	10.8	0.114
	Mothproof	1	24	24	11.9	0.118
		5	25	24	11.5	0.112
		10	23	26	11.2	0.108
7	Shrink-resistant	0	23	28	9.6	0.128
	Bacteria-resistant	1	24	28	10.8	0.134
	Mothproof	5	24	28	10.6	0.128
		10	23	29	10.7	0.130
8	Shrink-resistant	0	23	28	12.8	0.161
	Bacteria-resistant	1	28	24	12.8	0.168
	Mothproof	5	24	29	13.1	0.166
		10	24	29	13.2	0.162

approximately one ounce per square yard in weight. Blankets 1, 2, 3 and 7 had the greatest increase in weight (Table 1).

#### Thickness

Blankets 1, 2 and 3 showed the greatest increase in thickness. With the exception of number 4, which remained the same, all blankets were somewhat thicker after the first laundering, but thereafter there was a tendency toward a slight decrease (Table 1). The increase in thickness could be due to shrinkage.

#### Dimensional Change

Blankets 1 and 2 did not have a special shrink-resistant finish but were labeled machine washable. These two blankets have been referred to as controls (Figure I and II). Blankets 3, 4, 5 and 6 had the Dylanize treatment for shrink-resistance. Blankets 7 and 8 had treatments applied by the individual company but information was not available as to the type of process used.

Relaxation shrinkage occurred on all blankets as may be seen in Figure I, where warpwise shrinkage of one to five percent took place during the first washing. Felting shrinkage continued progressively on blankets 1 and 2. Blanket 7 showed a small amount of felting shrinkage. After the first laundering blanket 6 remained constant and blankets 3, 4 and 5 showed slightly decreased shrinkage values, which indicated slight lengthwise stretching.

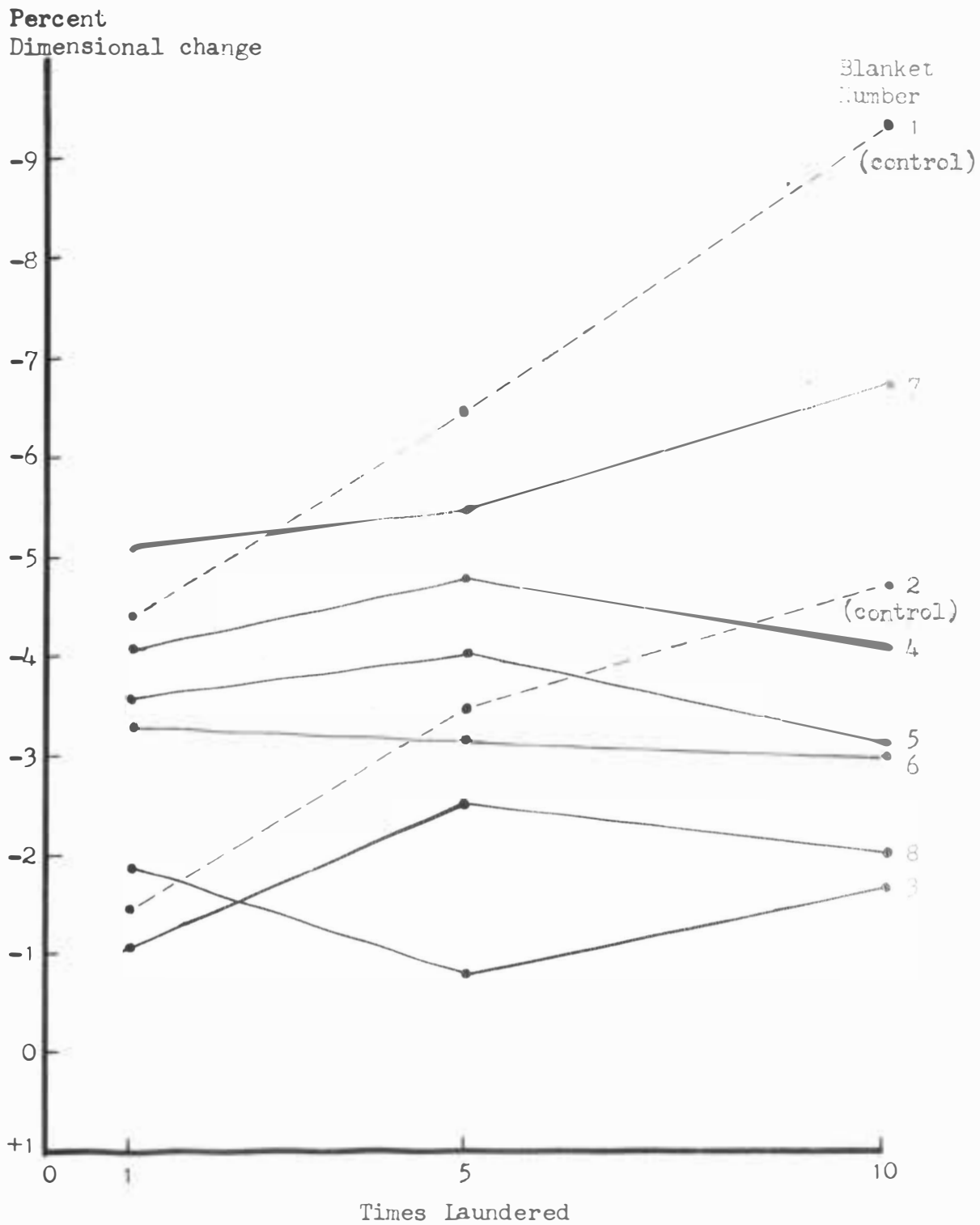


Figure I. Percent dimensional change in the warp (lengthwise) direction of eight blankets after laundering 1, 5 and 10 times

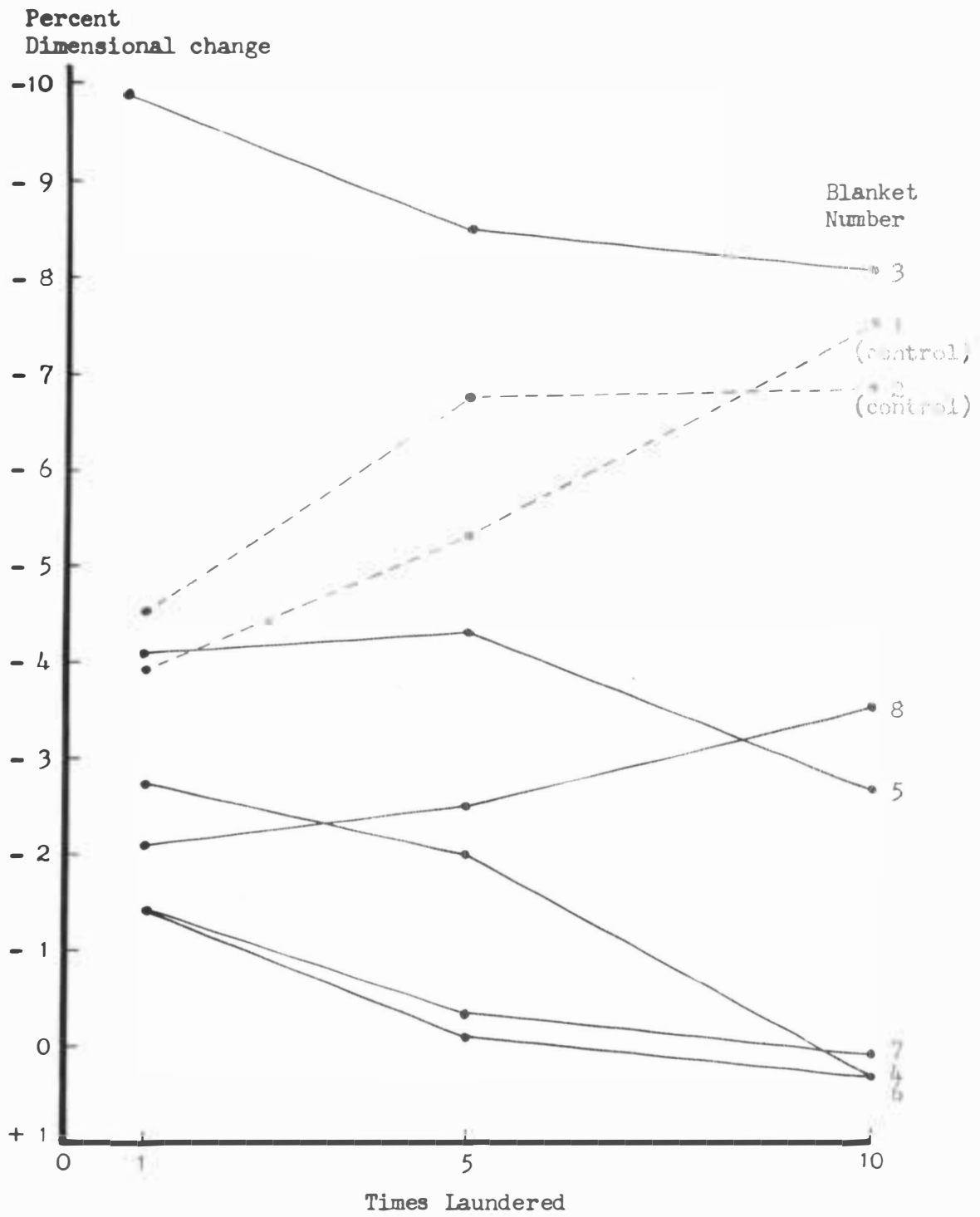


Figure II. Percent dimensional change in the filling (crosswise) direction of eight wool blankets after laundering 1, 5 and 10 times

In the filling or crosswise direction blanket 3 showed an excessive amount of relaxation shrinkage as may be seen in Figure II. Blankets 1 and 2 demonstrated the same pattern of relaxation and felting shrinkage as was present in the warp direction. Blankets 3, 4, 5, 6 and 7 had decreased shrinkage values. While blanket 8 showed progressive shrinkage, it was well within normal tolerance.

Adding the warp and filling shrinkage values to obtain area shrinkage, it appears that blanket 6 had the smallest amount of shrinkage. Blankets 4, 5 and 8 also gave evidence of good treatment for shrink resistance (Table 2).

#### Appearance and Hand

Although some shrinkage occurred, none of the blankets appeared to be heavily matted, pilled or otherwise unacceptable. The hand (feel) was good. In a few instances there was a slight color change but the appearance was still satisfactory (Exhibit A).

#### Antibacterial Properties

##### Qualitative Test

The qualitative test did not show a clear zone of inhibition adjacent to the specimen on either of the treated blankets 7 and 8 or on the control sample. Because of these results, additional qualitative tests were carried out using dilutions of one to one thousand and one to one hundred thousand. Neither of these dilutions produced a zone of inhibition around the blanket sample. The bacteria grew to the edge and also in the agar that covered each sample.



Table 2. Dimensional Change and Area Shrinkage  
After 1, 5 and 10 Launderings

Blanket number	Times laundered	Dimensional change		Area shrinkage (a + b)
		Warp (a)	Filling (b)	
1	1	-4.4	-3.9	- 8.3
	5	-6.5	-5.3	-11.8
	10	-9.4	-7.6	-17.0
2	1	-1.5	-4.5	- 6.0
	5	-3.5	-6.8	-10.3
	10	-4.8	-6.9	-11.7
3	1	-1.9	-9.9	-11.8
	5	-0.8	-8.6	- 9.4
	10	-1.7	-8.1	- 9.8
4	1	-4.2	-2.7	- 6.9
	5	-4.8	-2.0	- 6.8
	10	-4.2	+0.3	- 3.9
5	1	-3.6	-4.1	- 7.7
	5	-4.1	-4.3	- 8.4
	10	-3.2	-2.7	- 5.9
6	1	-3.3	-1.4	- 4.7
	5	-3.2	-0.1	- 3.3
	10	-3.1	+0.3	- 2.8
7	1	-5.2	-1.4	- 6.6
	5	-5.6	-0.3	- 5.9
	10	-6.5	+0.1	- 6.4
9	1	-1.1	-2.1	- 3.2
	5	-2.6	-2.5	- 5.1
	10	-2.1	-3.6	- 5.7

### Quantitative Test

The bacterial counts on the control blanket and the two blankets with antibacterial finish are shown in Table 3 and Figure III, respectively. The lowest count of bacteria was demonstrated by the control blanket which had no special finish. The control blanket showed an increased bacterial count after it was laundered once; thereafter the count continued to decrease.

Blanket 7 showed only a small increase in bacterial count during the first laundry interval. After the first laundering, blankets 7 and 8 followed the pattern of the control blanket which was a decrease in bacterial count with successive launderings (Figures IV, V and VI).

### Practical Test

The results of the practical test indicated presence of mold, colonies of bacteria and a spreader species on the control blanket and blankets 7 and 8. The amount of contamination in the air for that particular day determined the growth on the plates.

The spreader was plated out and found to be a spore forming aerobic species, Bacillus mycoides that produces a thermo-stable substance which inhibits the growth of many different species of bacteria, including Myco. tuberculosis (29). Bacteriacidal properties of Bacillus mycoides were apparent in that bacteria were counted after the plates had been incubated twenty-four hours. After forty-eight hours of incubation, the spreader seemed to overtake some of the bacteria that had been present in the first observation.

Table 3. Bacterial Counts on Control Blanket and Blankets Treated with an Antibacterial Finish Before Laundering and After 1, 5 and 10 Laundry Intervals

Blanket number	Laundry interval	Dilution	
		1/100,000	1/1,000,000
Control (no finish)	0	2,350,000	4,500,000
	1	33,650,000	60,500,000
	5	28,000,000	56,200,000
	10	14,350,000	30,200,000
7 (antibacterial finish)	0	60,620,000	71,200,000
	1	61,900,000	74,000,000
	5	32,100,000	61,000,000
	10	37,300,000	75,000,000
8 (antibacterial finish)	0	53,480,000	54,200,000
	1	46,600,000	50,800,000
	5	37,900,000	66,000,000
	10	25,550,000	42,800,000

There was not any indication that the antibacterial finish on the blankets inhibited growth of bacteria or mold.

It is difficult to draw a valid conclusion with the limited number of blankets that were used in this study with an antibacterial finish. At present blankets 7 and 8 continue to be available but mention of an antibacterial finish has been omitted from each. It is possible that the finish needs further research to make it effective.

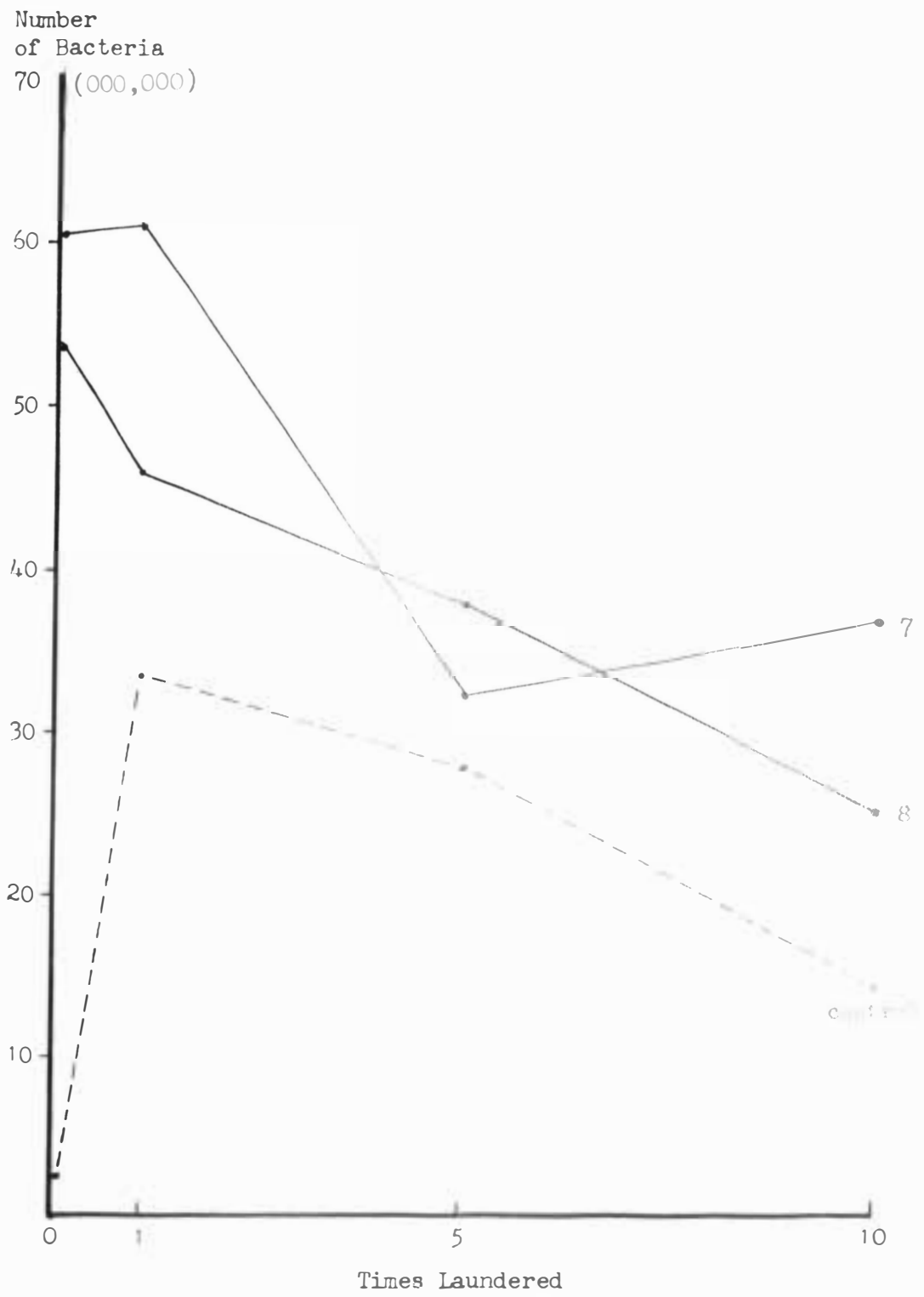
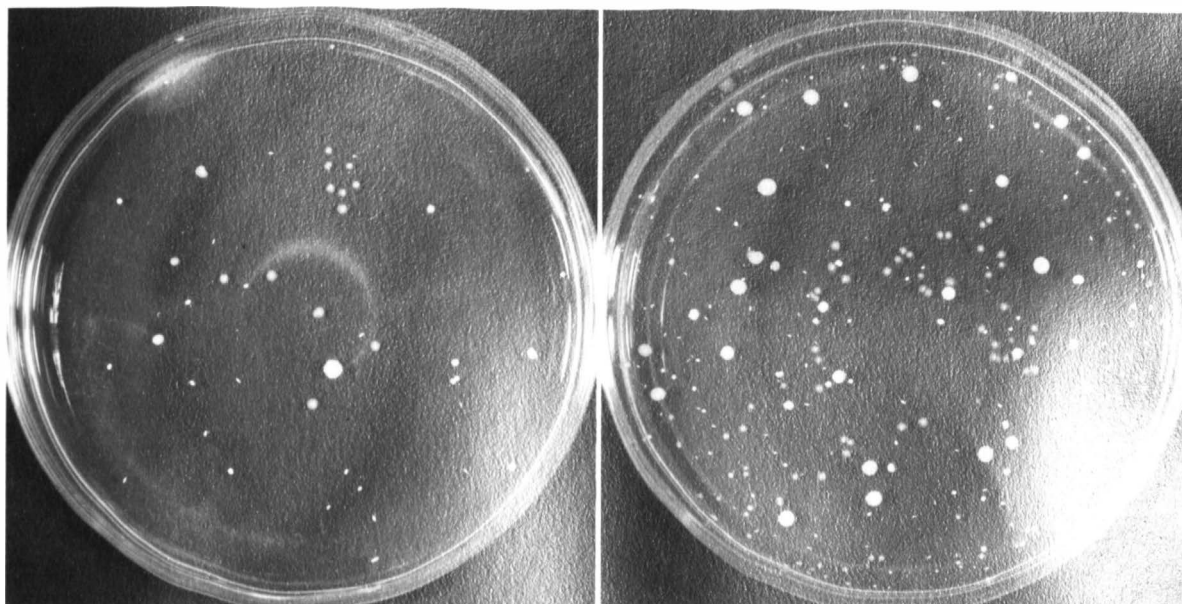
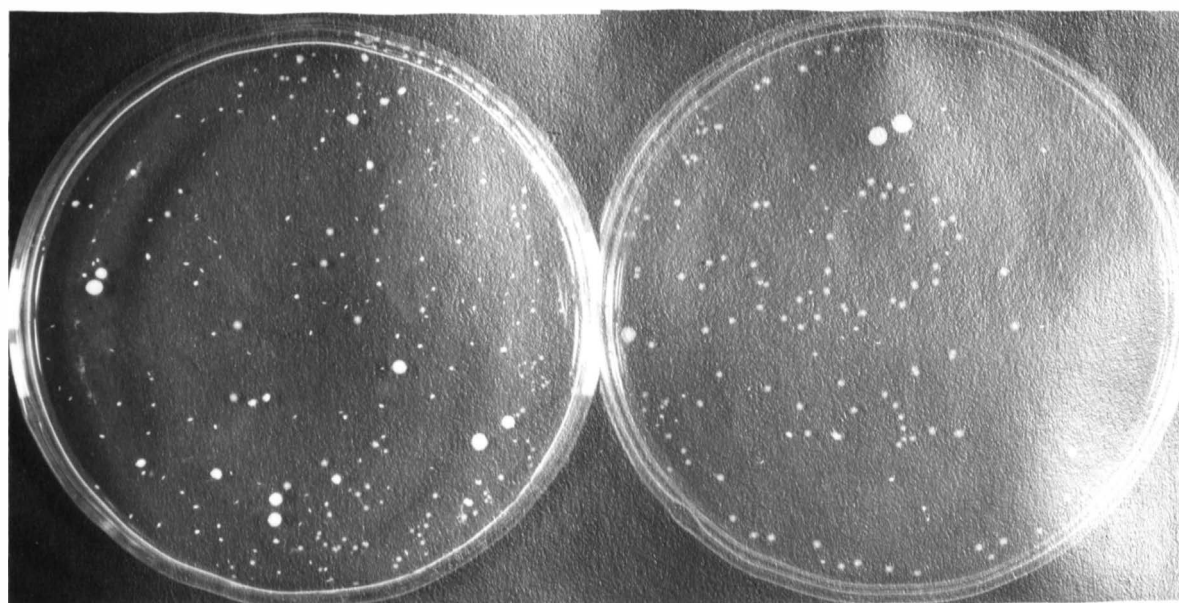


Figure III. Bacterial counts using 1/100,000 dilution on wool blankets before laundering and after 1, 5 and 10 laundry intervals



Not laundered

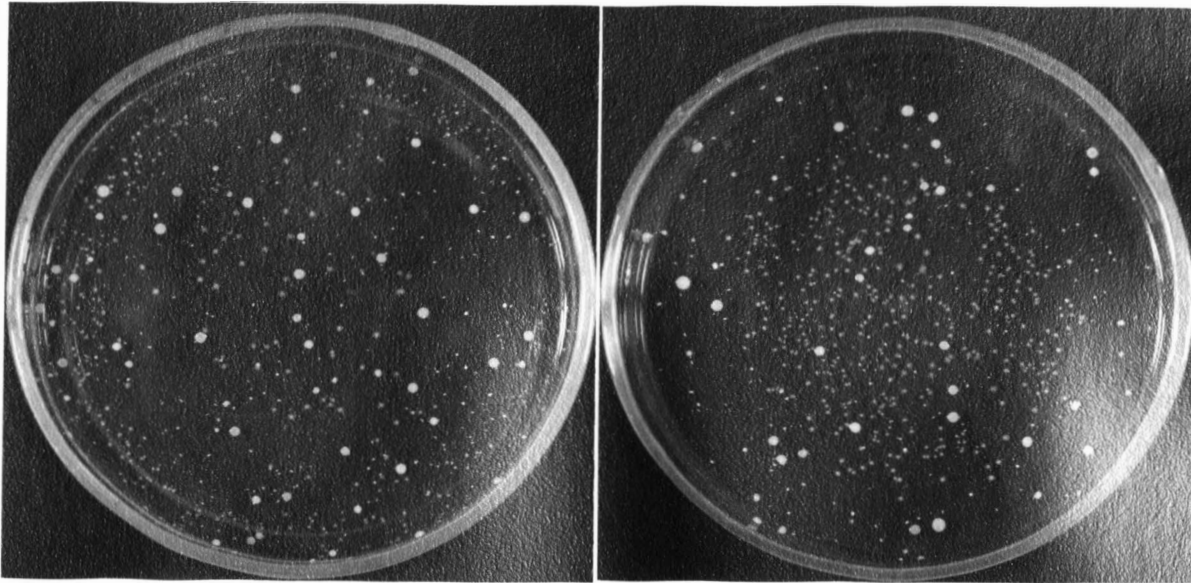
Laundered once



Laundered 5 times

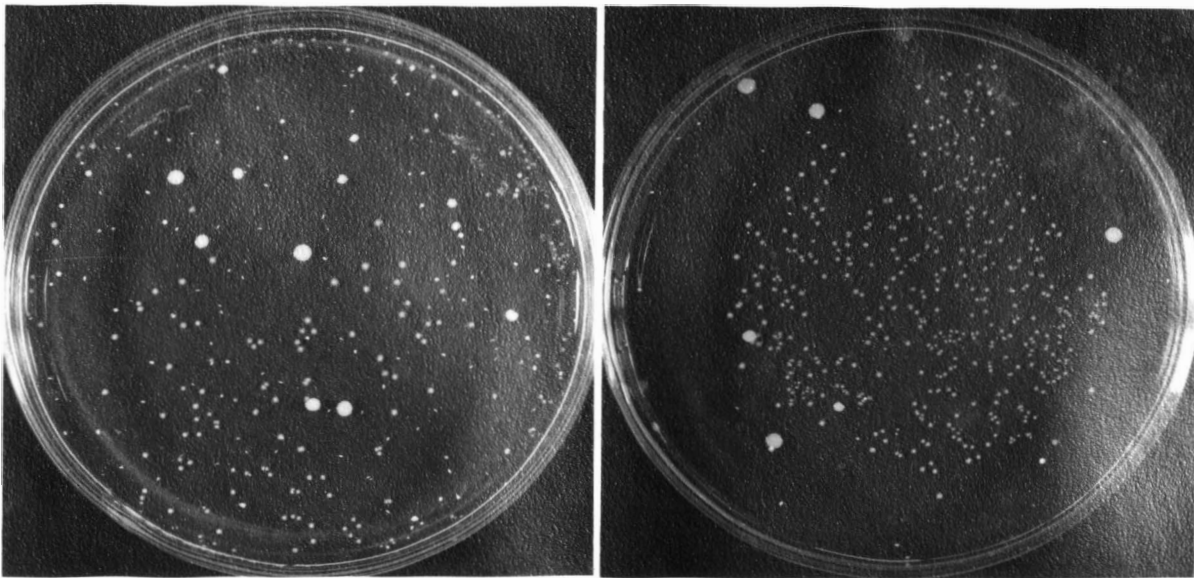
Laundered 10 times

Figure IV. Agar plates cultured  $1/100,000$  dilution for wool control blanket (without finish) before laundering and after 1, 5 and 10 laundry intervals



Not laundered

Laundered once



Laundered 5 times

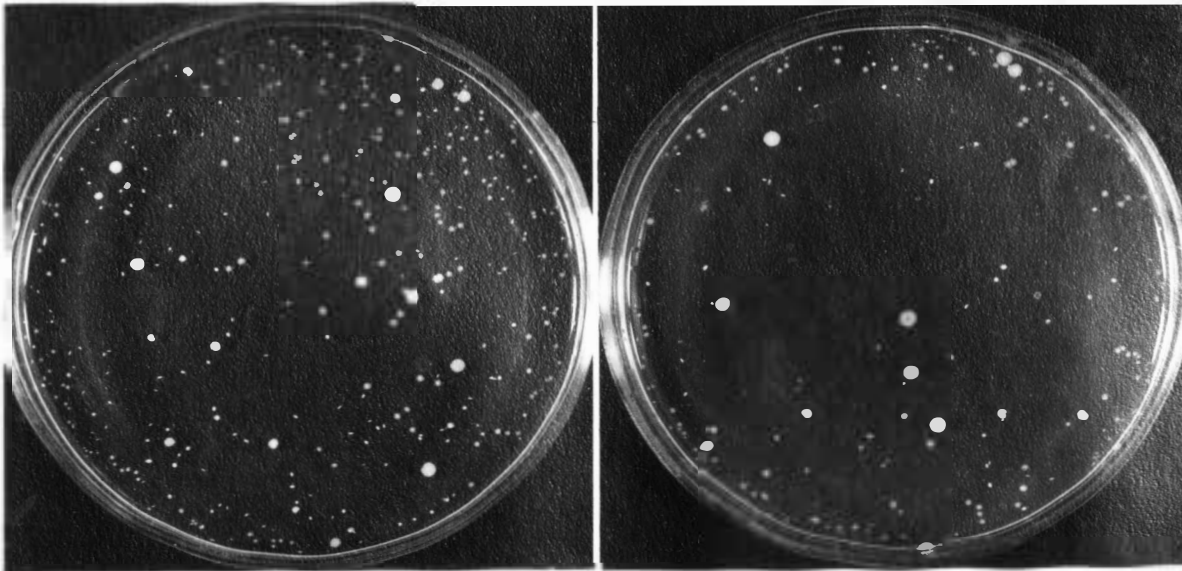
Laundered 10 times

Figure V. Agar plates cultured  $1/100,000$  dilution for blanket number 7 with antibacterial finish, before laundering and after 1, 5 and 10 laundry intervals



Not laundered

Laundered once



Laundered 5 times

Laundered 10 times

Figure VI. Agar plates cultured  $1/100,000$  dilution for blanket number 8 with antibacterial finish, before laundering and after 1, 5 and 10 laundry intervals

## SUMMARY

Wool blankets used in the study included two which were labeled machine washable and six with shrink-resistant finishes, two of which had antibacterial treatments. It was the purpose of this investigation to compare shrink-resistant finishes and their effectiveness on wool blankets after repeated launderings; and to determine effectiveness of antibacterial finishes on wool blankets after repeated launderings.

All blankets were laundered in an automatic home style washer using the slow setting on a two-speed machine. Agitation was stopped after two minutes. A pure soap and softened water of 80 degrees Fahrenheit were used. Each blanket was cut into four parts. One section was put aside for laboratory analysis; the others were randomly withdrawn for analyses after one, five and ten washings. The blankets were dried in an electric dryer and were removed as soon as the binding no longer felt damp (10 to 15 minutes) and were placed over lines to finish drying.

Physical characteristics such as fabric structure, thread count, weight and thickness were measured on the blankets.

Dimensional change was measured on the blankets after one, five and ten launderings. Results indicated that relaxation shrinkage of one to five percent occurred on all blankets in the warp direction and varied from one to nearly ten percent in the filling direction. With continued laundering several of the treated blankets showed slightly



decreased shrinkage values, which would indicate stretching had occurred. Others showed slight increases or remained the same. The untreated blankets continued to show shrinkage throughout the laundry intervals. Although shrinkage occurred, none of the blankets appeared heavily matted, pilled or otherwise unacceptable.

During the first laundering the relaxation shrinkage caused threads to become closer together and this resulted in an increase in weight of approximately one ounce per square yard. Thickness was affected in the same way. With the exception of one blanket which remained the same, all blankets were somewhat thicker after the first laundering but thereafter there was a tendency toward a slight decrease.

Evaluation of antibacterial finishes on fabrics necessitates consideration of the antibacterial activity intended in the use of the fabric. If only bacteriostatic activity (inhibition of multiplication) is intended, a qualitative procedure is sufficient. However, if bactericidal or disinfectant activity is intended, quantitative evaluation is necessary.

The American Association of Textile Chemists and Colorists Committee on Antibacterial Agents has recommended a two-part procedure (Tentative Test Method 100-1961T) consisting of a qualitative and quantitative test. This method was used for the evaluation of the antibacterial finishes on the blankets in this study. Staphylococcus aureus, strain 209 was used throughout the tests as the inoculum. The qualitative test selected was AATCC Agar Plate Method in which the

treated blanket is placed on agar seeded with the test organism. This test is dependent on the production of a clear zone of inhibition around the treated fabric. Additional tests using the inoculum in dilutions were made but none of the tests produced a zone of inhibition around the blanket sample.

The quantitative procedure involves inoculation of treated and untreated blanket samples with inoculum prepared in dilution, incubation of these samples, and subsequent enumeration of the bacteria. The lowest count of bacteria was demonstrated by the control blanket which had no special treatment. The control blanket and those with the antibacterial finish showed bacterial count decreasing throughout the successive launderings.

Before valid conclusions can be drawn on antibacterial finishes on wool blankets, further work needs to be done on methods of procedure so as to take into consideration the heavily napped structure of blankets and related problems.

## CONCLUSIONS

Within the limits of this study the following general conclusions might be drawn:

1. Relaxation shrinkage occurred during the first laundering regardless of the shrink-resistant treatments.
2. Dimensional change was within acceptable limits for five of the six blankets which had special shrink-resistant treatment. Felt-ing shrinkage continued progressively on untreated blankets which were labeled washable but had no shrink-resistant finish.
3. The lowest bacterial count was demonstrated by the control blanket which had no special finish.
4. The control blanket and those with antibacterial finish showed bacterial count decreasing throughout successive launderings.

## SUGGESTIONS FOR FURTHER STUDY

1. Determining effectiveness of a detergent which has been buffered to maintain a slightly acid condition on laundering wool blankets at high temperature.
2. Improving on methods of procedure which will give more valid results in measuring effectiveness of antibacterial finishes on heavily napped fabrics.
3. Determining rate of removal of antibacterial agents from textiles under the washing or drycleaning conditions normally used to clean the textile item.

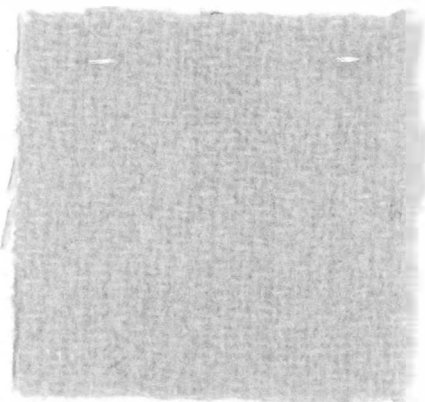
## LITERATURE CITED

1. American Association of Textile Chemists and Colorists, A.A.T.C.C. Technical Manual and Year Book. Vol. XXXIX, New York. 1963.
2. American Home Economics Association. Textile Handbook. 113 pp. Washington, D.C. 1963.
3. American Society for Testing Materials, Committee D-13. ASTM Standards on Textile Materials. Philadelphia. 1963.
4. Arnold, Luther B. "Antimicrobial Finishes for Textiles: Some Practical Aspects." American Dyestuff Reporter. 52:31-34. March 18, 1963.
5. Benson, Revel A., L. B. Slobody, Lois Lillick, Anthony Maffia and Norbert Sullivan. "A New Treatment for Diaper Rash." Journal of Pediatrics. 31:369-374. October, 1947.
6. Cowan, Mary L. Introduction to Textiles. New York: Appleton Century-Crofts, Inc. 1962.
7. Difco Manual of Dehydrated Culture Media and Reagents. Difco Laboratories, Detroit. 9th ed. 1953.
8. Fong, W., J. F. Ash and L. A. Miller. "Plant Trials of the Wurlan Shrink-Resist Process on Woolen Fabrics." American Dyestuff Reporter. 52:33-44. March 4, 1963.
9. Fong, W., R. E. Whitfield, L. A. Miller, A. H. Brown. "Wool Fabric Stabilization by Interfacial Polymerization." Modern Textiles. 42:30. November, 1961.
10. Frishman, Daniel and Milton Harris. "The Nature of the Modifications of Wool by Various Chlorination Processes and their effect on the Wear Life of Shrink-resistant Materials." American Dyestuff Reporter. 43:174-177. March 15, 1954.
11. Gagliardi, D. D. "Antibacterial Finishes." American Dyestuff Reporter. 51:31-40. January 22, 1962.
12. Hall, A. J. A Handbook of Textile Finishing. New York: Chemical Publishing Co., Inc. 1955.
13. Hall, A. J. "A New Look at the Shrink-resist Finishing of Wool." Textile Recorder. 79:59-61. March, 1962.

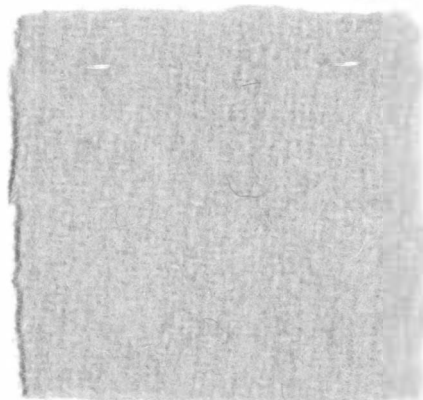
14. Hopkins, G. E. Wool as an Apparel Fiber. New York: Rinehart and Co., Inc. 1953.
15. "Key Controls in Shrinking Wool by Chlorination." Textile World. 110:96-97. May, 1960.
16. Kramer, Eugene N. "Antimicrobial Additives." Paper presented at the Disinfectant and Sanitizers Division Annual Meeting, Chemical Specialties Manufacturers Association, Hollywood, Florida. December, 1960.
17. Lindell, John. "Marker Organism Traces Bacterial Cross Infection." National Hospital. (Sydney, Australia) October, 1960.
18. Lund, Lillian O., Suzanne Davison and Mary O. Bloomquist. "Measuring Effects of Laundering on Blankets." South Dakota Farm and Home Research. 12:14-16. No. 4, 1961.
19. Lundgren, Harold P. "New Finishes for Easy-care Wool Fabrics." Modern Textiles. 41:53-56. June, 1960.
20. Macaluso, Charles P. "Wool." World Book Encyclopedia. 19:336-338. Chicago, Field Enterprises, Inc. 1963.
21. "Man-made Fibers and Yarns." Textile World. 109:67. September, 1959.
22. Matthews, J. M. Textile Fibers. New York: John Wiley and Sons, Inc. 1954.
23. McNeil, Ethel and Maurice Greenstein. "Control of Transmission of Bacteria by Textiles and Clothing." Paper presented by Ethel McNeil at the Joint Session Detergent and Cleaning Compounds Division and Disinfectant and Sanitizers Division Annual Meeting, Chemical Specialties Manufacturers Association. May, 1961.
24. McNeil, Ethel. "Detection and Evaluation of Antibacterial Activity of Treated Fabrics." American Dyestuff Reporter. 51:26-29. February 19, 1962.
25. McNeil, Ethel. "Evaluation of Antibacterial Finishes on Fabrics." American Dyestuff Reporter. 51:41-42. February 19, 1962.
26. McPhee, John R. "New Advances in Methods for Imparting Easy Care Properties to Wool Fabrics." Canadian Textile Journal. 79:43-47. January 5, 1962.

27. McPhee, John R. "Rate of Felting of Untreated and Shrink Resistant Wool Fabrics." Textile Research Journal. 31:770-778. September, 1961.
28. McPhee, John R. "Shrinkproofing Pure-Wool Blankets." National Hospital. (Sydney, Australia) October, 1960.
29. Merchant, I. A. and R. A. Packer. Veterinary Bacteriology and Virology. Ames, Iowa: Iowa State University Press. 1961.
30. Moncrieff, R. W. Wool Shrinkage and Its Prevention. New York: Chemical Publishing Co., Inc. 1954.
31. Morris, F. P. "Woolen Blankets Can Be Boiled." National Hospital. (Sydney, Australia) October, 1960.
32. Nagamatsu, George, Thomas Jefferson and Martin E. Silverstein. "A New Skin Treatment for the Incontinent Patient." Geriatrics. 4:293-302. 1949.
33. Pinault, Robert W. "Research Chief Reveals New Way to Shrink-proof Woolens." Textile World. 111:73. No. 6, 1961.
34. Pressley, T. A. "C.S.I.R.O. Research Findings Support the Use of Wool Hospital Blankets." National Hospital. (Sydney, Australia) October, 1960.
35. Russon, Wallace S. "Modern Methods for Producing Machine Washable Wool Products." Canadian Textile Journal. 80:41-43. February 15, 1963.
36. Somers, J. A. "Recent Developments in the Production of Antibacterial Fabrics." Textile Recorder. 80:67-71. October, 1962.
37. Sookne, Arnold M. "An Appraisal of Shrink-Resistant Treatment for Wool." Textile Research Journal. 27:652-661. August, 1957.
38. Steiger, Fred H. "Reducing the Felting Shrinkage of Wool." American Dyestuff Reporter. 50:37-44. February 6, 1961.
39. Stout, Evelyn E. Introduction to Textiles. New York: John Wiley and Sons, Inc. 1960.
40. Vonberg, Werner. Wool Handbook. Vol. 1. New York: Interscience Publishers. 1963.

Exhibit A. Swatches of Eight Wool Blankets before  
Laundering and after 10 Launderings

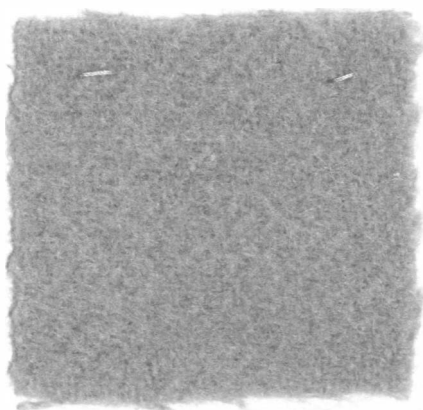


Before laundering

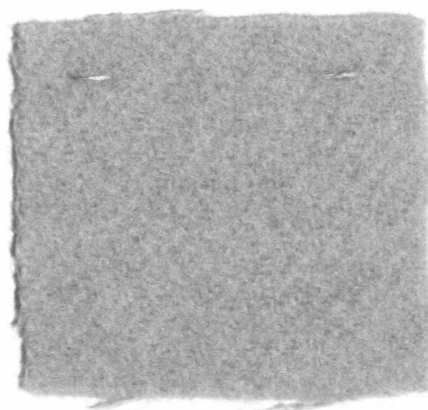


Laundered 10 times

Blanket Number 1



Before laundering

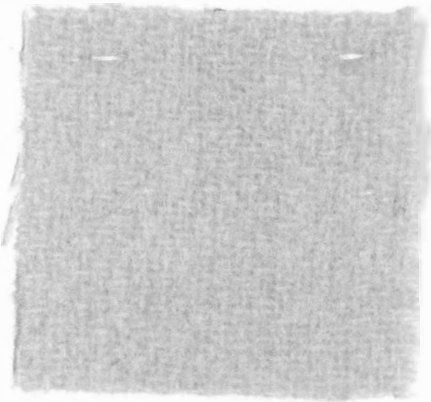


Laundered 10 times

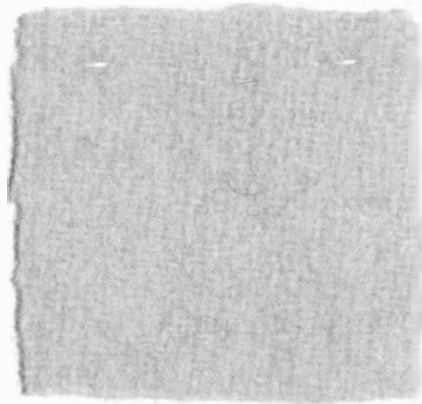
Blanket Number 2



Exhibit A. Swatches of Eight Wool Blankets before  
Laundering and after 10 Launderings

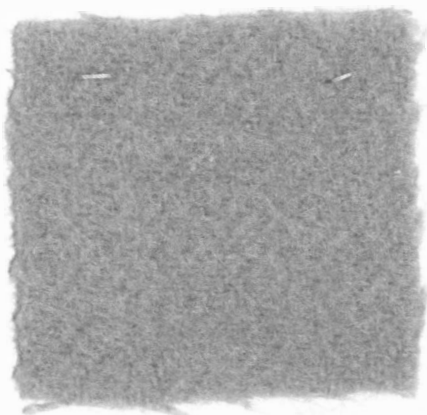


Before laundering

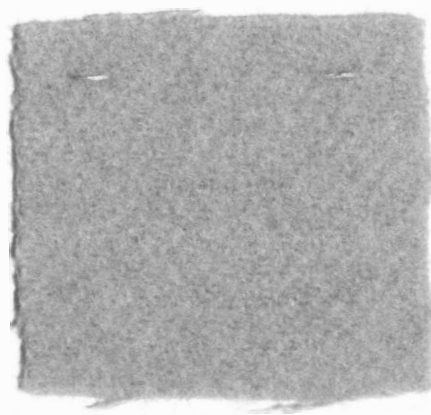


Laundered 10 times

Blanket Number 1



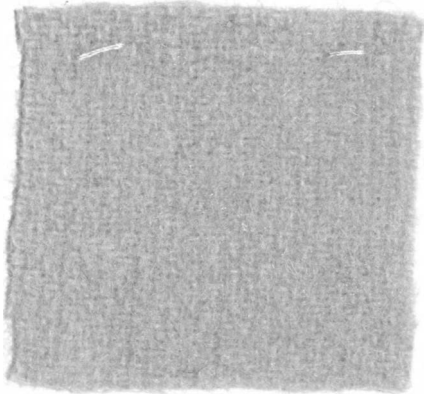
Before laundering



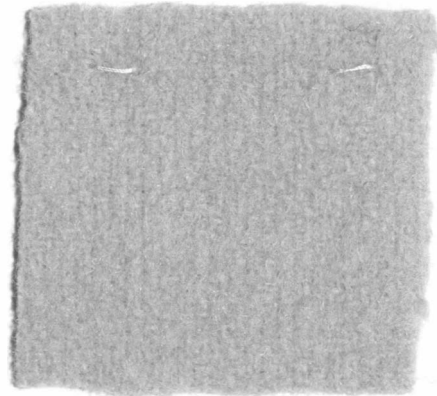
Laundered 10 times

Blanket Number 2

Exhibit A (continued)

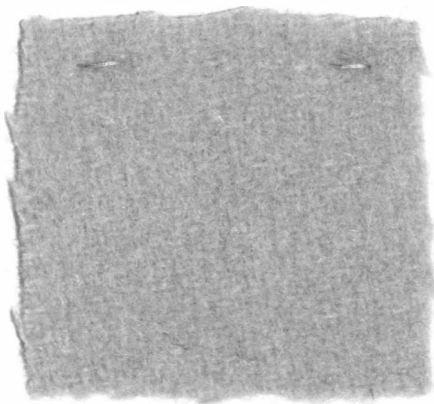


Before laundering

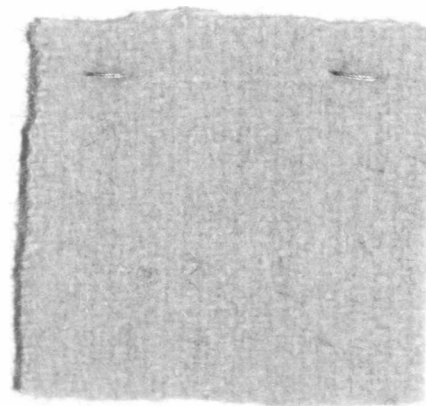


Laundered 10 times

Blanket Number 3



Before laundering



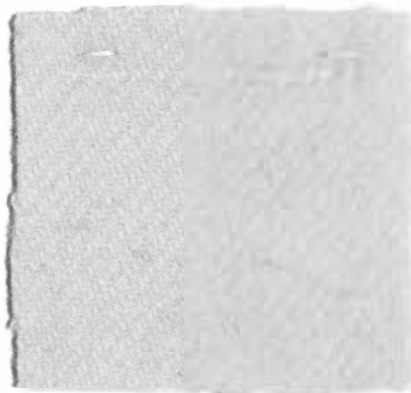
Laundered 10 times

Blanket Number 4

Exhibit A (continued)

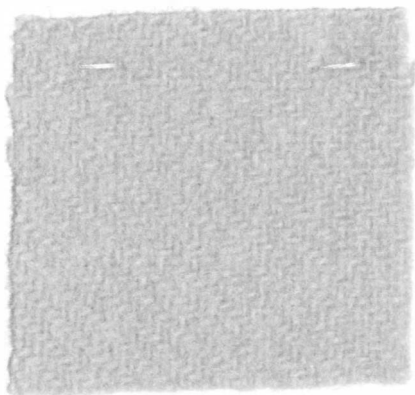


Before laundering

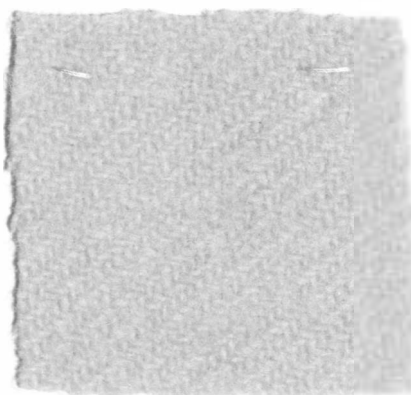


Laundered 10 times

Blanket Number 5



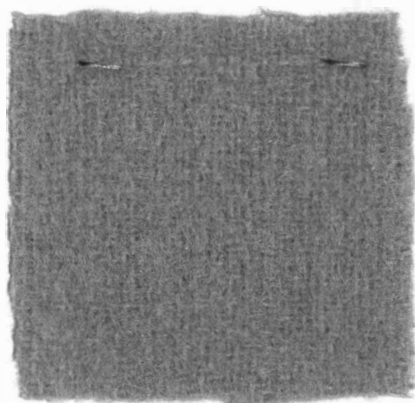
Before laundering



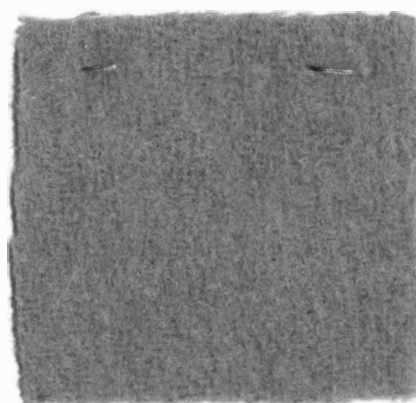
Laundered 10 times

Blanket Number 6

Exhibit A (continued)

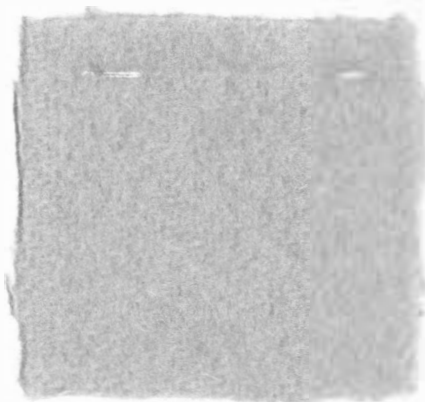


Before laundering

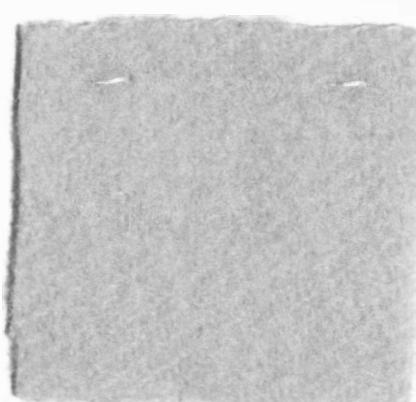


Laundered 10 times

Blanket Number 7



Before laundering



Laundered 10 times

Blanket Number 8