The comparative effects of soap and non-soap detergents in laundering wool in soft and hard water by Mary Grace Mytinger

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the degree of Master of Science in Home Economics
Montana State University
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Abstract:
The comparative effects of soap and non-soap detergents in laundering wool in soft and hard water were determined by the use of three different laundering methods. In the first method, five sets of infants' garments were soiled by actual wear and laundered twenty times each in a small hand washer. A specific detergent solution was used for each set: soap and distilled water, soap and tap water, Dreft (a non-soap detergent) and distilled water, Dreft and tap water, and soap in tap water softened by sodium hexametaphosphate. In the second method, five sets of samples from three white wool blankets containing various percentages of wool were soiled by a standard soiling solution, and washed in a lauderometer, using the same detergent solutions as above. In the third method, five sets of samples from the same white wool blankets were artificially soiled and laundered in a small washing machine which contained a larger amount of detergent solution and provided more agitation.

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THE COMPARATIVE EFFECTS OF SOAP AND NON-SOAP DETERGENTS

IN LAUNDRING WOOL IN SOFT AND HARD WATER

by

MARY GRACE MYTINGER

A THESIS

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ABSTRACT

The comparative effects of soap and non-soap detergents in laundering wool in soft and hard water were determined by the use of three different laundering methods. In the first method, five sets of infants' garments were soiled by actual wear and laundered twenty times each in a small hand washer. A specific detergent solution was used for each set: soap and distilled water, soap and tap water, Dreft (a non-soap detergent) and distilled water, Dreft and tap water, and soap in tap water softened by sodium hexametaphosphate. In the second method, five sets of samples from three white wool blankets containing various percentages of wool were soiled by a standard soiling solution and washed in a launderometer, using the same detergent solutions as above. In the third method, five sets of samples from the same white wool blankets were artificially soiled and laundered in a small washing machine which contained a larger amount of detergent solution and provided more agitation.

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THE COMPARATIVE EFFECTS OF SOAP AND NON-SOAP DETERGENTS
IN LAUNDERING WOOL IN SOFT AND HARD WATER

INTRODUCTION

The laundering of wool has always presented a number of problems. McGowan (38) states that "wool is the greatest collector of surface dirt and the most difficult to cleanse". The principal factors involved in these problems are the physical and chemical characteristics of the wool fiber that distinguish it from other fibers, and its reaction to the conditions and reagents used in the laundering process. Wool fibers are covered with flat, irregular, over-lapping scales that become inter-locked if the fibers are rubbed together or subjected to heat, moisture, or strong alkaline solutions. Chemically, the wool fiber is classed as a protein called "Keratin", which is characterized by its high sulfur content. When alkalies come into contact with wool, they remove a greater proportion of sulfur than nitrogen from the wool (53), thus causing partial decomposition and tendering of the fibers. Since soaps and other cleansing agents are generally alkaline in nature, there has been some reaction with the wool during the laundering process. If rinsing was not thorough, traces of soap remained in the wool fabric, gradually reacting with the fibers and causing some disintegration. The action of alkalies on wool increases as the temperature increases, so it has been necessary to use fairly low temperatures in working with wool.

Another important factor in the laundering of wool is the nature of
the water used. In certain sections of the country, the water contains compounds of calcium and magnesium which cause it to be called "hard water" (26). When soaps are introduced into hard water, a reaction occurs and insoluble calcium and magnesium soaps are formed. These produce a scum or curd on the surface of the water, and this gray material clings to wool fabrics immersed in the water. It is difficult to rinse this curd out of the laundered articles, and a grayish tint finally develops on the fabric. Natural "soft" water or rain water does not contain calcium and magnesium compounds, so does not present this problem in laundering, and is very desirable for use in textile woolen mills. When hard water is softened, the insoluble compounds are either removed or the calcium and magnesium ions are replaced with sodium (26). However, these processes are expensive and the water is often over-treated, especially in home laundering. The problem of dealing with hard water is important in Montana. While on the whole, the state is reported as having water of average hardness (26), some sections of the state have water with a high degree of hardness.

A few years ago, some new non-soap detergents were developed in the form of sulfated or sulfonated higher fatty alcohols. These compounds were found to have good sudsing properties; were not alkaline in nature; and, since they were not soaps, did not form insoluble calcium and magnesium soaps in hard water, thus eliminating curd formation. The manufacturers claim that they may be used in smaller quantities than soap, that they will cleanse more efficiently in any type of water, and will produce a good suds in water through a wide range of temperature. These claims, if verified, would place these non-soap detergents in a position of distinct advantage for the laundering of wool in hard-water regions.
Since some of these non-soap detergents are now appearing on the market, and since there is little definite information about their efficiency in relation to soaps for laundering wool, this study has been made to compare the effects of soap and non-soap detergents for laundering wool in soft and hard water, considering especially their relative cleansing power, their relative effect on the qualities of the wool fabrics, and the relative appearance of the laundered articles.

HISTORY OF DETERGENCY

Water and Agitation. The early history of laundering is concerned with the agitation of water to remove soil from garments. Therefore, water was the first detergent to be used and its place as a detergent may be traced back about three thousand years. Streams made the best laundry spots because the water was naturally in motion, but cleansing was only partial at best. Various aids for agitating the water were gradually developed by primitive people. Natives in India, the Phillipines, Russia, Panama, and Jamaica shook or twisted their clothes in the water or kneaded them on stones or boards. The Egyptians and Turks trod their clothes in the water. The Swiss threw them on inclined boards and pounded them with paddles. The use of pounding was wide-spread but was hard on the clothes (8). Cold water was the outstanding feature of primitive washing and hot water did not come into use until early in the nineteenth century, when the need for sterilization was recognized. The principle of water agitation used in all modern washing machines was inspired by the various primitive washing methods.
Early Development of Detergent Compounds. The use of detergent compounds in addition to water goes back to an early date. The Chinese utilized herbs and barks as cleansers (8). These usually contained saponins that foamed readily (22). "Soap tree bark" may even be purchased today.

The word "soap" was used by the prophets Jeremiah and Malachi, but they may have been referring to the ashes of plants, which had some cleansing properties. The earliest account of soap making is given by Pliny, who described the combining of goats' suet and ashes of the beech tree by the early Gauls (18). The product obtained was a soft potash soap, which was converted into a hard soda soap by treating the paste repeatedly with salt. Later the wood ashes were replaced by soda ashes from sea plants, kelp, barilla, etc. (5). It was also known that ashes of shore plants yielded a hard soap and ashes of land plants a soft one.

A well-equipped soap factory was found in the ruins of Pompeii, and soap was being used in Italy and Spain in the eighth century (4). The soap-making industry spread into Germany and was introduced into France in the thirteenth century. At this time the manufacture of olive oil soap was begun at Marseilles. In England, the soap trade was started in the fourteenth century. During the reign of Charles I, a soap-making monopoly was developed by a corporation of soap boilers in London. Heavy excise duties were levied on soap made in England, but in spite of this the industry expanded rapidly (5). In the sixteenth century, urine came into use as a cleansing agent because of its alkalinity and has continued until rather recently (8).

In America, soap making began as a household art in which fat from the
dripping pan was used to make a soft soap. A number of Germans and Poles skilled in handling fat and soap ashes came to the colonies in 1608; thus, the making of soap soon became one of the principal colonial industries. By 1795, small soap-boiling establishments were located in nearly all the large towns (4).

In the eighteenth century, interest became centered on the alkaline material needed for soap-making. In 1736, du Monceau discovered that common salt and the ashes of sea plants had the same base as was found in natural deposits of soda salts, "mineral alkali", and that it differed from the "vegetable alkali" obtained by burning land plants or wood (2). In 1791, Leblanc revolutionized the soap-making industry with his discovery of a process for manufacturing soda from brine (5). This process made possible the large-scale production of soda and was utilized thirty years later by American chemical manufacturers and soap-makers. Chevreul in 1815, first showed the true chemical nature of animal and vegetable fats and oils and thus raised soap-making from a trade practice to a scientific process (15).

At first the American soaps were of a very common grade, but by 1835, American manufacturers were supplying all of the home demand and also exporting a considerable amount. Gradually more complex methods were used, new machinery was developed for the various steps in the process, filling materials were added to the soaps, and fancy products began to appear on the market.

Theories of Detergency. For a long time, the detergency or cleansing power of the various agents in use was accepted as an existing fact. Finally, scientists began to question the property of detergency and try to explain
the underlying principles. In the nineteenth century Chevreul, a French chemist, found that soaps are hydrolyzed by water to form free alkali and an acid salt (24). Berzelius (5) and later Persoz (18) attributed detergent power to the free alkali produced by hydrolysis. Jevons (18) observed pronounced Brownian movement of particles suspended in a soap solution. He thought the soap loosened and washed away the dirt particles. Kolbe (18), in 1880, suggested that cleansing action was due to saponification of the fat surrounding the dirt particles by the alkali from the hydrolyzed soap. Subsequently, the dirt particles were entrapped by the foam, thus permitting mechanical removal of the dirt. Wright (18) suggested that detergent action required that the substance to be cleaned should be "wet" and that the "wetting power" of soap solutions was due to the alkali present.

Plateau (18) and Quinke (18) studied emulsifying agents and substances which foam and ascribed the power of forming bubbles, films, and foams to high surface viscosity and low surface tension. In collaboration they showed that soap solution has a surface tension lower than that of any other aqueous solution. Quinke found that no pure liquid would foam, so he concluded that the permanence of foam was caused by the mixed character of the liquid.

Krafft and Wiglow (18) in 1895 pointed out that the more concentrated soap solutions did not show the freezing point lowering or the boiling point elevation that would be expected of true solutions. On these grounds, they stated that soap solutions were colloidal. Donnan (16) concluded that the lowering of interfacial tension and consequent emulsification resulted from the formation of a colloidal layer or membrane at the interface.
Ladenburg (18) quotes Knapp as claiming that the cleansing action of a soap is due to its property of "easily wetting oily substances, penetrating into the capillaries of the goods, and acting as a lubricant, making the tissues and impurities less adhesive to one another and thus promoting dirt removal".

Previous to 1903, nearly all of the theories of detergent action had their origin in the belief that the alkali of hydrolysis of soap was the active agent in cleansing. In 1903, Hillyer (24) published the results of an investigation in which he concluded that the cleansing power of soap was largely or entirely to be explained by its ability to emulsify oily substances, but that the emulsifying power of soap could not be attributed to alkali of hydrolysis. He showed (25) that the surface tension between soap solution and oils diminishes as the concentration increases and that low surface tension and emulsification are closely related.

The colloid theory received added impetus after 1908, when many investigations brought up evidences to support it. At about the same time, the effect of surface tension and interfacial tension on cleansing power became the object of studies. Jackson (18) in 1908 observed Brownian movement on examining soiled fabrics immersed in soap solutions under the microscope and called attention to the influence exerted by soap on the state of subdivision of the dirt. These observations agreed with the earlier findings of Jevons, and Krafft and Wiglow on the colloidal nature of soap solutions. He also stated that lather was a sign of detergency but was not necessary for cleansing. He discovered that, although lowering of surface tension does not always parallel foaming power, the alkali soaps lower sur-
face tension markedly and produce large amounts of foam.

In 1909, Spring (18) disproved the previous conceptions of dirt as being of a fatty or oily nature or coated with fat or oil by showing that the detergent action of soap was unimpaired by using lamp black which had been freed of all fatty or oily material. This led to the conclusion that cleansing by soap was due to the formation of a sorption compound, dirt and soap, instead of the sorption compound, dirt and fabric.

Donnan and Potts (18) in 1910 held that the lowering of interfacial tension was an important factor in the stabilization of the soap solution and foam or lather. Bottazzi (10) in 1913 claimed that pure soaps do not affect surface tension, but that the addition of hydroxides to soaps decreases the surface tension. He explained this by stating that unhydrolyzed molecules lower surface tension and alkalies increase the concentration of unhydrolyzed molecules. Bowden (11) in 1911 concluded that soaps could not be simple colloids because high values obtained for the conductivity of even the most concentrated soap solutions proved that much electrolyte was present. On the other hand, he stated that there was a colloid present in soap solutions and that therefore the colloid must be the acid sodium salts.

Farrow (19) in 1912 disagreed with Bowden by stating that "in not too dilute aqueous solutions, the alkali salts of the higher fatty acids are to be classed as electrolytic colloids, since these solutions conduct the electric current and yet show relatively small changes of vapor pressure and boiling points." McBain and coworkers (18, 34, 35) measured the hydroxyl ion concentration in soap solutions and found it to be about N/1000. They reported that a transition from a typical simple electrolyte to a neutral
colloid may be observed with any fatty acid salts on change of temperature or concentration. Through measurements of conductivity, osmotic activity, and alkalinity of soap solutions, they demonstrated that soaps are "typical colloidal electrolytes" in concentrated solutions but that on dilution they break down into simple salts.

In 1920 McBain and Salmon (37) made measurements of the osmotic pressure of various soap solutions, which showed that in extreme cases the sodium or potassium ion is the only constituent that is not a colloid. This ion, being present in high concentration, must be counterbalanced by a "colloidal micelle of high equally opposite charge and conductivity".

McBain and Laing (36) in 1920 experimented on the characteristics of soap sols and soap gels and concluded that they are identical in all respects except that the gel form alone has elasticity and rigidity. They defined a soap curd as being "a sol or gel from which a part or nearly all of the soap has been abstracted through the formation of white curd fibres". The soap curd is distinguished by the separation of hydrated soap as a felt of long, white, microscopical fibers. A transparent soap is a plain gel. All other hard commercial soaps are gels with felts of curd fibers.

Pickering (43) in 1917 combined several of these theories by saying that the detergent action of soap "is due in part to its power of emulsifying oil, --- in part to the lowness of surface tension between oil and the soap solution, and perhaps in part to the union of dirt with the acid soap produced by hydrolysis ---. Oils ---- dissolve in soap to form soluble compounds".

Millard (39) stated in 1923 that the chief function of a soap is that
of an emulsifying agent for greasy material on the dirt to hold it in suspension. In the same year Stericker (51) claimed that suds lift the dirt out of the wash solution, thus preventing the dirt from being redeposited on the fabric.

Linder and Zickerman (18) concluded that wetting power is most closely related to lathering tendency and thought that too great emphasis had been laid on the lathering power of soap. However, Bertram (9) said that the cleansing action of soap depends on its surface tension against air, interfacial tension against the fabric and dirt, frothing power, and stability of the froth. Rehbinder and Trapeznikov (45) measured surface viscosity and foam stability of sodium oleate solutions and found that the initial foam volume rises steadily to a soap concentration of 0.1 per cent and remains constant through 1.5 per cent, the limit of their measurement. Their observations showed that the maximum foam stability is reached at a concentration just short of saturation of the surface layer.

The next advance in the study of detergency was concerned with the effect of positive and negative ions upon cleansing action. Vincent (52) in 1927 stated that soap solution will suspend solid particles because the solid particles adsorb negative ions from the solution, thus becoming charged. The positive ions are also adsorbed from the solution, and the extent to which the ions are adsorbed determines the stabilization of suspended particles. The concentration of the soap solution must be such that there is strong adsorption of the positive ion. There will be no stabilization if the positive and negative ions are adsorbed to the same extent. Vincent (52) also found that the optimum concentration of soap for suspending solids,
which is 0.2-0.4 per cent, is more than enough to emulsify oils, which require 0.05-0.1 per cent. The reason that highly concentrated soap solutions are good detergents is that these solutions are very efficient wetting and emulsifying agents.

Other studies have been made on the effect of pH on the detergent action of soap as influenced by soap builders—substances which are added to soap to increase its detergent power. The alkaline salts most commonly added to soaps as builders are sodium carbonate and bicarbonate, sodium phosphates and silicates, borax, and caustic soda. They possess detergent properties of their own to varying degrees. Since the detergent action of a solution is increased by increasing the amount of colloidal material present, and since hydrolysis decreases the formation of colloids, materials which will decrease hydrolysis are added to the soap. In recent years, many investigators have made studies of the relative efficiencies of these various alkaline salts by comparing them on the points now deemed necessary for detergency.

Vincent (52) found that sodium phosphate is valuable as a detergent for greases containing calcium oleate because it forms a sodium soap with the oleate. Sodium hydroxide, sodium silicate, and sodium carbonate soften iron waters in the order named.

Rhodes and Bascom (47) made a study of the effect of pH on the detergent action of soap and found that hydrogen ion concentration plays an important part in washing efficiency. The maximum efficiency of the soap solution was found to be pH 10.7. Of the builders used, sodium hydroxide, trisodium phosphate, and sodium carbonate showed the greatest detergent
effect at a pH of 10.0. They concluded that the amount of increase in detergency caused by the builder at the optimum alkalinity depends to a large extent on some specific property of the anion of the builder, perhaps its valence.

Snell (49) stated that one of the main points in selecting a salt to increase the detergency of a soap solution is the alkalinity it produces on hydrolysis. He also claimed that the comparison must be made on the initial hydroxyl ion concentration before reaction and on the total alkalinity available after the reaction has started. He believes that a soap builder is useful in washing only as long as it maintains an alkalinity in solution greater than that corresponding to a pH of 10.0.

In studying the lowering of interfacial tension caused by alkaline salts, Snell (50) discovered a general parallelism between interfacial tensions and the pH of the alkaline salt solution. Relatively highly alkaline soap builders can partially replace soap in effect on interfacial tension. However, the alkaline salts alone will not lower the interfacial tension of water against benzene. Sodium hydroxide caused the greatest interfacial tension lowering when added to soap. Sodium orthosilicate and sodium metasilicate were next in order.

Baker (7) investigated the detergent value of sodium metasilicate and found it to have high wetting and emulsifying powers, strong dirt suspending powers, and the ability to dissolve alkali-soluble dirt, although that factor depends on the pH of the solution and the amount of contained sodium oxide that will react with the dirt. He showed that less soap is required when alkali is used. If an alkali is to be effective in protecting the
soap from decomposition, it must have a pH of at least 10.5 and should have enough reserve alkali or be sufficiently buffered to keep the hydroxyl ion concentration at the prescribed point after part of it has been used up by neutralization. When the pH is maintained above 10.5 a smaller amount of soap is required.

Trisodium phosphate (48) also ranks high as a detergent. Its power to emulsify oils is said to approach that of a colloidal emulsifying agent. A large number of household detergents now have trisodium phosphate as a base, and it is recommended for fine laundering in the home. The fact that it produces no suds is not to be regarded as hindering its detergent ability.

Research carried on at Pennsylvania State College (42) on the effect of builders in washing showed that the alkalies used did not affect the fabric strength to any degree. Soda ash, sodium metasilicate, and trisodium phosphate were the alkalies used. Soda ash was required in the smallest amount, 1 part to 2-3 parts of soap; sodium metasilicate, 1 part to 2 parts of soap; and trisodium phosphate, 1 part to 1-2 parts of soap.

Gillet (21) found that tetra sodium pyrophosphate has a powerful peptizing action on particles of solid dirt, grease, and insoluble soaps, thus suspending the particles uniformly throughout the washing solution and preventing them from collecting on the fabric being washed. It also has a colloidal effect on the soap, which increases the lathering power and detergency of the soap.

One of the most recent theories of detergency is that which concerns the action of cations and anions. Kulkarni and Jatkar (32) measured interfacial tensions of sodium and potassium soaps against benzene and concluded
that surface activity is mainly dependent on the nature of the anions. As the anions get concentrated at the surface, the cations form a double layer with oriented anions. Thus, the simple mols, which are entirely dissociated, show the most surface activity. Henk (23) found that materials which depress surface tension act as cleansing agents only if they promote dispersion of soil particles. Therefore, cation active products are not good cleansers since they neutralize the charge on dirt particles and cause them to stick to the fabric.

According to Warwicke (54), soap and most other detergents are anion-active. The behavior of wool washed with anionic-and cationic-active soaps is cited as an example. When it is washed in a mildly alkaline solution of soap or a sulfated fatty alcohol, it is cleaned easily. However, if a cationic soap is added, the action is reversed and the soap and dirt may be redeposited on the fiber. The cationic soaps (55) are suitable for washing in slightly acid solutions. This is often useful in washing wool which contains lime and mineral salts.

The modern theories of detergent action claim that it depends on wetting power, emulsifying ability, dissolving power, alkalinity and ionic activity. Thus, a number of the old theories of detergency have been revived and incorporated into the modern idea that detergency is due to several different factors.

Modern Detergents. The search for new detergents (17) probably began in Germany during the World War, when there was a shortage of the fats necessary for soap manufacture. Attention was turned toward the sulfonated oils, which had been used in the textile industry as soap substitutes be-
cause they were good sudsing and wetting agents in acid solutions and were not affected by hard water, but they were not very good detergents. It was sulfonated oils that inspired the search for the ideal detergent.

In the straight-chain sulfonated oils (17), the sulfuric radical is generally attached to the fatty acid or hydrocarbon chain by breaking a double bond and linking up as a side chain. Research workers reasoned that the detergency of soap is due to the basic group being attached to the end carbon of the chain, "while in the sulfonated oils it is attached through the sulfonic group to an inside carbon".

It was Bertsch (17) who first pointed out that the COOH group would have to be either eliminated or "blocked" by sulfonation or sulfation of the end carbon. Schrauth (31) in 1928 applied for patents covering his invention of a method of "hydrogenating fatty oils and fatty acids to yield the corresponding alcohols and the preparation from these of sulphuric acid derivatives whose properties closely approach those of the ideal detergent". Although this was not the first method of changing fatty oils and fatty acids to their corresponding alcohols, it was the first one which could be used on a commercial scale.

Schrauth's method consists of using higher temperatures and pressures plus catalysts to permit the hydrogen to "react with the -COOH group in the fatty acid molecule and to reduce it to an alcohol group (-CH₂OH) or to a hydrocarbon group (-CH₃), depending on the points at which these variables are controlled". Under the old method of low temperatures and pressures, the only change was hydrogenation or the breaking of double bonds and the subsequent addition of hydrogen to the molecules. Lazier (31) in the United States patented a similar method of hydrogenation in 1932. Since
then, the commercial development of the non-soap detergents has been comparatively rapid.

These new compounds are supposed to possess all the advantages of soap without any of the disadvantages. Briscoe (12) lists their properties as follows:

1. Excellent wetting-out powers.
2. Excellent emulsifying powers.
3. Much greater cleansing powers than soap.
4. Adequate stability to acid solutions, as the free acids are soluble in water.
5. Complete stability to alkalies.
6. Failure to separate alkali on hydrolysis, and hence suitability for uses in completely neutral solution.
7. Complete resistance to sea water.
8. Good lathering properties.
10. Pronounced "fatty" character.
11. Stability on storage, with no development of rancidity.

Another group (17) of new detergents comes under the class of the sulfated alcohols. They are the sulfuric esters of the straight-chain fatty alcohols ranging from eight to eighteen carbons or more, and are called hymolal salts, the term "hymolal" probably referring to the high molecular weights. The sodium salts are white solids that are more crystalline than soap. They have some characteristics in common, but vary among themselves according to the length of the carbon chain. Increasing the molecular weight
causes a corresponding increase in detergent power and lower solubility of
the hymolal salts.

The solubility of the metallic hymolal salts parallels considerably
that of their corresponding metallic sulfates. The metallic radical appar­
tently does not affect detergency but combines the characteristics of the
metal with the good wetting and detergent properties of the alkyl sulfate
group.

Salts of three different sulfated alcohols are made:

1. Sulfated alcohols in the range C₁₆ to C₁₈.
   Sodium octa-decyl sulfate: \( \text{CH}_3(\text{CH}_2)_{16}\text{CH}_2\text{OSO}_3\text{Na} \).

2. Saturated alcohol sulfates in the range C₁₀ to C₁₄.
   Sodium lauryl sulfate: \( \text{CH}_3(\text{CH}_2)_{10}\text{CH}_2\text{OSO}_3\text{Na} \).

3. Unsaturated alcohol sulfates in the range C₁₆ to C₁₈.
   Sodium oleyl sulfate: \( \text{CH}_3(\text{CH}_2)_{7}\text{CH} = \text{CH}(\text{CH}_2)_{7}\text{CH}_2\text{OSO}_3\text{Na} \).

Products from saturated alcohols of the range C₁₀ to C₁₄ have made the
greatest impression in this country and seem to have the widest range of
usefulness. Coconut, or palm kernel oils are hydrogenated with high temper­
atures and pressures and then are usually fractionally distilled to make
the alcohols. The sodium salt, sodium lauryl sulfate, is marketed as
"Gardinol WA" in the textile trade, as "Orvus" in the non-textile bulk
trade, and as "Dreft", in a spray-dried granulated form, to the retail trade.
In hard water, these compounds form calcium salts at temperatures much be­
low 100°F, but they redissolve readily when warmed.

The salts of the other two sulfated alcohols have extensive use in the
textile field. Octa-decyl alcohol is made from sperm oil or by high pres-
sure hydrogenation of tallow or other suitable animal and vegetable oils. It is marketed as the sodium salt for use at temperatures of 130°F and higher and also has a limited solubility of calcium salts at lower temperatures. Oleyl alcohol is obtained from sperm oil. There is difficulty in sulfonating it without some sulfonation of the double bonds, therefore, the commercial product is a mixture of the sulfate ester and sulfonate.

The Igepons (17), "Igepon A" and "Igepon T", comprise another class of synthetic detergents with the following formulae:

\[
\text{Igepon A: } \text{CH}_3(\text{CH}_2)_7\text{CH} = \text{CH}(\text{CH}_2)_7\text{COOCH}_2\text{CH}_2\text{SO}_3\text{Na}.
\]

\[
\text{Igepon T: } \text{CH}_3(\text{CH}_2)_7\text{CH} = \text{CH}(\text{CH}_2)_7\text{CONCH}_2\text{CH}_2\text{SO}_3\text{Na}.
\]

Igepon A is made by combining isoethionic acid or its salt with oleic acid or its derivatives. It cannot be used with alkalies since they "split the molecule at the carboxyl group with the formation of soap". Igepon T was developed to correct this difficulty. It is similar to Igepon A but has better resistance to both acid and alkaline solutions.

Lamepons (14) are a more recently developed group of detergents. They are made by condensing fatty acid chlorides with protein decomposition products from leather waste to yield the following product:

\[
\text{C}_{17}\text{H}_{33}\text{CONHR}((\text{CONHR}_2)_\times \text{COONa}.
\]

Their ability to disperse lime soaps is attributed to the large number of \(-\text{CONH-}\) groups and their aliphatic chains and protein nature give them surface-active and protective properties. They are recommended for all uses of soaps and wetting agents.

The Igepals (56) are purely synthetic detergents, no natural substances
being used in their production. Their general formula is \( R_1 \text{OR}_2 \text{OR}_2 \text{O-OR}_2 \text{CH} \), \( R_1 \) being a "hydrophobic, aliphatic straight or branched-chain hydrocarbon residue which functions like the hydrocarbon chain in the long-chain soap-like detergents", and \( R_2 \) being "short-chain units, usually \( \text{C}_2 \text{H}_4 \), each connected with the rest by ether-oxygen bridges, except for the group at the end of the molecule, which is usually a hydrophyl group". In aqueous solution the solubility is aided by the formation of new hydroxyl groups at the oxygen atoms due to residual valencies. This results in the development of weak negative charges which cause the salt to act as a soap-like colloidal electrolyte and produce detergency. Igepal C is recommended for use with vegetable fibers and all synthetic fibers except cellulose acetate. Its properties are similar to those of other non-soap detergents, including easy solubility, practically unlimited resistance to all metallic salts, ability to remove oils, solid fats, dirt and loosely adhering dyestuff, and a protective colloidal action on the lime salts of ordinary soaps. Igepal W is used for woolens. It has properties similar to those of Igepal C.

One of the newest synthetic detergents is Nacconol NR (41), which is an alkyl aryl sodium sulfonate. Its properties are said to be very similar to those of the Gardinols. In addition, it is a water-softener, dispersing lime-soap curds into a very finely divided form that is readily removed from the fabric in the rinse. It is also resistant to the action of strong acids and alkalies. It does not make as much foam as soap, but foams more rapidly due to its greater solubility.

Sulfanole FB (3, 6) is another new detergent which is similar to the sulfonated fatty alcohols. It is an aliphatic fatty derivative and is
chemically neutral.

Lucy (33) carried on washing tests with wool using a number of sodium alkyl sulfate detergents and soap, with the result that the soap used, an olive oil chip soap, ranked ninth out of ten in cleansing action. He concluded that each of the detergents should be used under the right conditions for best results, because they are variously affected by different factors, such as temperature and time of cleaning action. He also considered that the best way to measure cleaning action is by the direct method.

Jones (30) found that during laundering, wool adsorbs much more soap than synthetic detergent, but that cotton adsorbs about the same amount of all kinds of detergents.

Hulme (27) classifies modern detergents as anionic and nonionic types. The anionic type contains the surface-active radical as a negatively charged ion and includes the Gardinols, Igepons and Macconal. The nonionic type includes Igepals.

Water Softeners. Since much of the water available for household and commercial laundering contains mineral compounds that cause hardness, the softening of laundry water has become a major problem throughout the country. When soap is used to soften water, it forms insoluble compounds with the calcium and magnesium salts in the water, these compounds forming what is known as curd. The curd settles out, thus making the water soft toward additional soap.

Some of the compounds which were discussed as soap builders are also efficient water softeners. The sodium phosphates (21) have been used as softeners for many years. With trisodium phosphate, the phosphate radical
combines with the calcium and magnesium to form insoluble compounds, the same as soap. However, these calcium and magnesium phosphates do not have the undesirable characteristics of stickiness and sliminess that are possessed by the soap curd.

The sodium and potassium pyrophosphates have a strong water-softening effect. Sodium pyrophosphate keeps iron in solution, dissolves iron oxide from fabrics, and increases the lathering power of soap in hard water. Sodium hexametaphosphate in solution has a pH of approximately 6.5, but when used with enough alkaline material to raise its pH to 8.5, it is very effective in softening water. Its chief advantage as a water softener lies in the fact (21) that it "binds the calcium and magnesium in hard water in soluble form so that water can be made alkaline and treated with soap and no precipitation of any kind will occur." This action is known as water "normalizing". When used as a rinse for fabrics that have been washed in hard water, it will remove insoluble soaps that have been picked up in the wash.

Two new water softeners are sodium monothiotetraphosphosphate and sodium trithiotetraphosphosphate (13). They may be used with soap in any proportions. If the water is treated with the thiotetraphosphate and the soap is added afterward, the lather forms in large bubbles, but if the soap and thiotetraphosphate are added together, finer and denser suds are formed.

EXPERIMENTAL PROCEDURE

In planning the experimental work for studying the comparative effects of soap and non-soap detergents in laundering wool in soft and hard water,
two methods of approach were chosen. The first portion of the experiment consisted in subjecting white woolen infants' garments to soiling by actual wear and laundering them by a home method, that will be described in detail. The second part of the experiment consisted in laundering artificially soiled white wool blankets by a standard laboratory method, and in the third section, artificially soiled white wool blankets were laundered by a home method.

Home Laundering Method

A. Garments Laundered. Six infants' shirts, white and knitted of a mixture of wool, cotton and rayon yarns (about 10 per cent wool), and six pairs of infants' hose, white and knitted of wool and silk yarns (about 12 per cent wool), were secured for use in this part of the study.

Each new shirt was weighed and measured in the following places as shown in figure 1:

1. Width of sleeve at wrist.
2. Width of sleeve at shoulder.
3. Length of sleeve from shoulder to wrist.
4. Length of shirt from shoulder to bottom edge.
5. Width of top of shirt from shoulder to shoulder.
6. Width of shirt at underarm.

Each new hose was weighed and measured in the following places as shown in figure 1:

1. Length from top to bottom of heel.
2. Width at top of leg.
3. Width of leg at a point 12 cm. up from the junction of the
4. Width of leg at junction of the leg and foot.
5. Length of foot from the toe to back of heel.

One shirt and one pair of hose were reserved for the standard textile tests enumerated below. The tests were done according to A. S. T. M. Designations No. D 231-33 and No. D 403-36 (1).

1. Number of wales and courses per inch.

A thread counter was used and the average of five counts was taken.

2. Tensile strength.

a. Bursting strength in pounds per square inch.

The Mullen tester was used and the wheel was turned at a rate of 30 times per 15 seconds. The shirt was burst in ten places and the average computed. Each hose was burst in ten places in the leg and three places in the foot and the average of leg and foot computed separately.

b. Yarn tensile strength.

Tests were made by the single strand method using the Suter machine. Since the shirts had rayon stripes, 5 rayon yarns and ten of the other yarns were tested from the upper and lower fronts and the back. Ten yarns each from the knee, ankle, and foot were tested from the hose. Readings included tensile strength and per cent of stretch.
The other five shirts and five pairs of hose were worn in rotation by the baby at the Home Management house, each set being worn and laundered twenty times. The girls at the Home Management house cooperated by filling out the following forms for each wearing of the garments:

<table>
<thead>
<tr>
<th>SHIRT MARK</th>
<th>STOCKING MARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Date</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Time put on</td>
<td>Time put on</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td>Time taken off</td>
<td>Time taken off</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Was shirt taken off during day?</td>
<td>(usual</td>
</tr>
<tr>
<td>Why?</td>
<td>Activity</td>
</tr>
<tr>
<td></td>
<td>(more than usual</td>
</tr>
<tr>
<td></td>
<td>(less than usual</td>
</tr>
<tr>
<td>Activity (more than usual)</td>
<td>Stains (kind)</td>
</tr>
<tr>
<td>(less than usual)</td>
<td></td>
</tr>
<tr>
<td>Stains (kind)</td>
<td></td>
</tr>
<tr>
<td>How many times was diaper changed while shirt was worn?</td>
<td>How many times was diaper changed while stockings were worn?</td>
</tr>
</tbody>
</table>

Before the garments were laundered for the first time, they were steeped for twenty minutes in a one per cent solution of borax in distilled water at 40° C. to remove any acid left in the new wool (28).

B. Washing Method. The washing was done in a small hand washer of the suction-cup type. Two liters of water at 40° C. were put into the washer and the detergent was added. Fifty strokes of the plunger were used to dissolve the detergent and raise the foam. One set of soiled garments, consisting of one shirt and one pair of hose, was placed in the solution and washed for three minutes at a rate of 90 to 95 strokes per minute. The water was then gently squeezed out of the garments and they were rinsed for one minute in two liters of water at the same temperature and rate of
strokes, then gently squeezed dry. This rinsing process was repeated a second time. The garments were next rolled in a towel, then laid on a cloth on a flat surface, pulled into shape, and covered with another cloth while drying.

C. Water. The soft water used was ordinary laboratory distilled water. The hard water was Bozeman city water which had a total hardness (40) of 108 parts per million or 6.34 grains per gallon. Calculated according to Jackman and Rogers (29), 0.657 grams of soap would be required to soften one liter of water of that hardness.

D. Detergents. The detergents selected for use in the experiment were Ivory soap flakes and Dreft, which represent soap and non-soap detergents, respectively. Ivory flakes are a white soap with a low degree of alkalinity of the type recommended for laundering fine and delicate fabrics. Dreft is a non-soap detergent belonging to the class of sulfated alcohols, being sodium lauryl sulfate, a Cardinal. It is also recommended for use with fine and delicate fabrics in any kind of water.

The concentrations of the detergent solutions were decided upon according to some previous studies (28) on the laundering of wool and also from the results of foaming and surface tension tests. The foaming test measures the foaming ability of a detergent solution and determines the stability of the foam. The test was conducted by agitating one liter of detergent solution at 40° C. with fifty strokes of the plunger in the small hand washer. Then the solution and foam were poured into a large graduated cylinder and measured. The rate at which the suds broke down was also noted. The surface tension test was carried out with the Traube stalag-
mometer, using the method of Findlay (20). The surface tension of water and detergent solutions were compared by the drop method against air.

A 0.37 per cent solution of soap in distilled water was selected as the standard (28), and four other detergent solutions were made to approach its characteristics as closely as possible. There was apparently no available information concerning the amount of Dreft to use in home laundering, so it was necessary to establish concentrations for Dreft solutions that appeared to be comparable in foaming ability to the soap solutions.

The five detergent solutions used in the laundering test were as follows:

1. A 0.37 per cent solution of Ivory soap in distilled water.
2. A 0.37 per cent solution of Ivory soap in tap water plus 0.065 per cent of soap for softening the water. (For the first rinse, a 0.065 per cent solution of soap was used. Ten strokes of plunger were used to mix the soap and water.)
3. A 0.2 per cent solution of Dreft in distilled water.
4. A 0.2 per cent solution of Dreft in tap water.
5. A 0.37 per cent solution of Ivory soap in tap water plus 0.1 per cent of sodium hexametaphosphate for softening the water. The amount of sodium hexametaphosphate required to soften the water was set at one gram per liter because that amount, when used with a 0.37 per cent solution of soap in tap water, agreed in the number of drops from the stalagmometer with that of a 0.37 per cent solution of soap in distilled water. (The sodium hexametaphosphate was added first and the plunger given ten strokes
to dissolve it, then the soap was added. A 0.1 per cent solution of sodium hexametaphosphate in tap water was used for the first rinse, the plunger being given ten strokes to dissolve the phosphate.)

Each set of garments was always washed in the same detergent solution throughout the test. At the end of twenty washings per set, the garments were compared for appearance and relative cleanliness and then subjected to the same textile tests as the original set.

Standard Laboratory Method

A. Analysis of Blankets. Three blankets, one unnapped containing 100 per cent wool, one containing 75 per cent wool, and one containing 40 per cent wool, were used. Each blanket was given the following tests according to A. S. T. M. Designation No. D 39-36 (1):

1. Weight per square yard in grams.
2. Length and width. (Five measurements of each were taken and averaged.)
3. Tensile strength.
   a. Breaking strength, grab method, using the Scott tester. (Five samples, each 4 by 6 inches, were cut from both the warp and filling directions and the breaking strength averaged for each.)
   b. Bursting strength on the Mullen tester, the wheel being turned at a rate of 30 strokes in 15 seconds. (Ten samples, 4 by 4 inches, were tested and the average strength computed.)
c. Yarn tensile strength on the Suter machine. (Ten yarns each of warp and filling were tested and the average calculated.)

4. Twist count on the Precision twist counter. (Ten yarns each of warp and filling were tested and averaged. There was a distance of 4 inches between the clamps, as specified by A. S. T. M. Designation No. D 403-36 (1). The number of twists per inch was thus obtained.)

B. Standard Soiling Method. Thirty samples, 4 by 6 inches in size, were cut on the warp and also on the filling from each blanket, and appropriately labeled. The samples were soiled with a standard soiling solution which was a modification of that recommended by the Detergent Committee of the American Oil Chemists Society (46). It consisted of:

- 2 liters of carbon tetrachloride
- 0.4 gram lampblack
- 3 grams tallow
- 5 grams lubricating oil.

The method of soiling varied slightly from that recommended by Rhodes and Brainard (46). The solution was shaken well and 50 cc. were poured into a 14.5 cm. diameter evaporating dish. The sample was then held by the corners and run through the solution once, then held at a twenty-degree angle until liquid no longer ran from it in a steady stream. It was next placed between two eight-layer thicknesses of gauze and pressed with the hands. The above process was repeated with fresh portions of soiling solution for each of the samples, after which they were dried in an oven for an
hour at 80°C ± 10°C. Then they were allowed to age in air for twelve or
more hours, before being laundered. The samples were soiled in groups of
twenty, all samples within the group being identical.

C. Standard Laundering Equipment and Method.

1. Equipment. The washing was carried on in a launderometer con­
structed according to the accepted standards of the American
Association of Textile Chemists and Colorists. It consists of
twenty pint jars firmly clamped into a rotor, which revolves at
the rate of 42 r.p.m. in a tank of water heated to a desired
temperature.

2. Laundering Procedure. The procedure was adopted from A. S. T. M.
Designation No. D 436-37 (1). In each pint jar was placed one
blanket sample, 100 cc. of detergent solution and ten rubber
balls, 12.88 mm. in diameter and weighing 1.89 grams each, for
increased agitation. All detergent solutions were made up and
warmed before being put into the jars. The wash lasted for
thirty minutes at a temperature of 38°C ± 2°C. Then the jars
were emptied, the samples squeezed and put back into the jars
together with the balls. The rinse of 100 cc. was added, the
machine run for one minute, and the samples removed and squeeze­
ed. Rinsing was repeated twice more and the samples were then
squeezed, stretched out and laid to dry on gauze on a flat sur­
face.

3. Detergent Solutions. The soap solution was selected according to
A. S. T. M. Designation No. D436-37 (1). The strength of the
Dreft solution was determined by the use of a direct ratio with the strengths of the soap and Dreft solutions used in the first part of the experiment.

Jars No. 1 and 2 contained samples No. 1. Distilled water was used for the wash and rinse. Samples No. 2 were placed in jars No. 3, 4, and 5 and washed and rinsed with tap water. Samples No. 3 were placed in jars No. 6, 7, and 8. They were washed with a 0.5 per cent solution of soap in distilled water and rinsed in distilled water. Samples No. 4, in jars No. 9, 10, and 11, were washed in tap water containing 0.5 per cent soap plus 0.065 per cent soap for softening the water. The first rinse was tap water plus 0.065 per cent soap to soften the water, while the second and third rinses were tap water alone. Jars No. 12, 13, and 14 contained samples No. 5. The wash solution was distilled water plus 0.27 per cent of Dreft and the rinses were distilled water. Samples No. 6 were in jars No. 15, 16, and 17 and were washed in a 0.27 solution of Dreft in tap water and rinsed in tap water. Samples No. 7 were washed in jars No. 18, 19, and 20, which contained a solution of tap water plus 0.5 per cent soap and 0.1 per cent sodium hexametaphosphate. The first rinse was a 0.1 per cent solution of sodium hexametaphosphate in tap water, while the other two rinses were tap water alone.

4. Description of the Washes. The first wash was run without samples, in order to determine the condition or turbidity of the detergent solutions alone. The second wash was done with clean samples of
100 per cent wool blanket, half of which were cut on the warp and half on the filling. The third wash used similar clean samples of 75 per cent wool blanket. The fourth wash was done with clean 40 per cent wool blanket samples. The remaining six washes were done with the artificially soiled samples.

D. Determination of Cleansing.

1. Turbidity tests. The detergent solutions from each jar in each wash were kept and tested for the percentage of turbidity resulting from the laundering process, by means of a photo-electric colorimeter. The galvanometer was set at 100 with a tube of distilled water as the standard, and the various wash solutions gave readings between 100 and zero according to their degree of turbidity. From these readings was calculated the concentration of the material suspended in the wash solution.

2. Color Tests for Cleanliness. When the samples laundered in the various detergent solutions had been dried, they were compared for cleanliness by analyzing their color in a color comparator (Bausch and Lomb). Samples of the original material and of artificially soiled material were also color analyzed as checks on the laundered samples.

Combination of Home Laundering and Laboratory Methods

A. Blanket Samples Used. Ten samples, 4 by 6 inches in size, were cut from each of the three blankets used in the second part of the experiment.
The samples were artificially soiled as previously described.

B. Washing Method. The washing was done in a small washer of the gyrator type having a capacity of about five gallons. Six liters of water at 40°C were put into the washer and the detergent was added. The machine was run for thirty seconds to dissolve the detergent and raise the foam. Two soiled samples from each blanket were then put into the solution and the washer was allowed to run for ten minutes. The samples were then rinsed twice by hand in two liters of warm water.

C. Detergents. The detergent solutions were of the same concentration as those used in the second part of the experiment.

D. Determination of Cleansing. Turbidity tests were run on the detergent solutions before the samples were added and after the wash was finished. The blanket samples were compared for cleanliness by analyzing their color in the color comparator.

DISCUSSION OF RESULTS

The results obtained from these experimental tests, which were designed to determine the comparative effects of soap and non-soap detergents in laundering wool, are presented in tabular form. Tables I-IV contain data showing the effects of the five different detergent solutions used in the home laundering method on woolen garments that had been soiled by actual wear. The efficiency of each detergent was judged on the basis of its effect on the fabric and the degree of cleanliness obtained.

In table I, the results of laundering are shown by comparing the fabric construction and measurements of knitted woolen shirts when new and
after being laundered. There were no indications of appreciable shrinkage with any of the detergents, according to wales and courses per inch or to measurements of the garments. Any decrease in one direction appeared to be compensated by an increase in the other direction. There was a very slight increase in the per cent of stretch of the wool and cotton yarn in the laundered garments, while the rayon yarn showed a definite increase in stretch after being laundered.

When samples containing identical numbers of yarn loops were cut from each garment and weighed, those from the laundered garments weighed slightly more than the new fabric. This would indicate that some substance, possibly "curd" or soil, had adhered to the laundered fabrics. These increases were more noticeable in the samples laundered with tap water and soap, distilled water and Dreft, and tap water and Dreft.

Table IX presents data of a similar type with regard to knitted woolen hose. An increase in the count of wales and courses per inch of the laundered hose over that of the new hose shows that there was some shrinkage in all of the laundered hose. The measurements of the hose indicate that the greatest shrinkage was in the length of the leg. All of the hose that were worn and laundered lost weight, probably through wear. However, the hose laundered with tap water and Dreft lost only about one-half as much weight as the others. Since all of the hose were apparently subjected to equivalent amounts of wear, this smaller loss of weight might have been caused by the failure of the detergent solution to remove all of the soil.

The data in table III show the comparative strengths of the knitted woolen garments when new and after being laundered with the various detergents. Bursting strength, a specific measurement for knitted fabrics,
Fig. 1. Drawings of shirt and hose, showing where measurements were taken.
Table I. Fabric Construction and Measurements of Knitted Woolen Shirts When New and After Being Laundered with Various Detergents

<table>
<thead>
<tr>
<th>Items</th>
<th>No. of tests</th>
<th>New garment</th>
<th>Similar garments laundered 20 times in</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dtd. Water and Soap</td>
<td>Tap Water and Soap</td>
</tr>
<tr>
<td>Av. Wales/in. ............... 5</td>
<td>25.4</td>
<td>21.4</td>
<td>21.5</td>
<td>21.4</td>
</tr>
<tr>
<td>Av. Courses/in. ............. 5</td>
<td>36.5</td>
<td>41.6</td>
<td>42.5</td>
<td>40.8</td>
</tr>
<tr>
<td>Av. Yarn Stretch (p.c.t.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool and Cotton Yarn. ........ 60</td>
<td>1.5   (1.0-2.5)</td>
<td>1.8 (1.0-3.1)</td>
<td>1.8 (1.1-2.6)</td>
<td>1.6 (0.2-2.6)</td>
</tr>
<tr>
<td>Rayon Yarn .................. 30</td>
<td>3.0 (2.0-4.0)</td>
<td>3.8 (3.0-6.0)</td>
<td>3.8 (2.6-4.6)</td>
<td>3.3 (2.0-5.5)</td>
</tr>
<tr>
<td>Wt. of a Square</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 Wales x 58 Courses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Shirts (gms.)............ 30</td>
<td>.377</td>
<td>.386</td>
<td>.402</td>
<td>.400</td>
</tr>
<tr>
<td>Laundered Shirts ............ 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
Table I. (Concluded) Fabric Construction and Measurements of Knitted Woolen Shirts When New and After Being Laundered with Various Detergents

<table>
<thead>
<tr>
<th>Items</th>
<th>No. of tests</th>
<th>New garment</th>
<th>Similar garments laundered 20 times in</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dtd. Water and Soap</td>
<td>Tap Water and Soap</td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td>-------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td><strong>Measurements (cm.)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>New Shirts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a to b</td>
<td>5.5</td>
<td>5.6</td>
<td>5.3</td>
<td>5.5</td>
</tr>
<tr>
<td>c</td>
<td>10.7</td>
<td>11.0</td>
<td>10.9</td>
<td>10.7</td>
</tr>
<tr>
<td>a</td>
<td>18.8</td>
<td>19.1</td>
<td>19.3</td>
<td>19.2</td>
</tr>
<tr>
<td>c</td>
<td>28.7</td>
<td>28.8</td>
<td>28.6</td>
<td>28.4</td>
</tr>
<tr>
<td>c</td>
<td>16.1</td>
<td>16.1</td>
<td>15.4</td>
<td>16.0</td>
</tr>
<tr>
<td>d</td>
<td>15.5</td>
<td>15.9</td>
<td>15.6</td>
<td>16.2</td>
</tr>
<tr>
<td><strong>Laundered Shirts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a to b</td>
<td>6.9</td>
<td>6.1</td>
<td>6.5</td>
<td>6.0</td>
</tr>
<tr>
<td>c</td>
<td>10.4</td>
<td>10.1</td>
<td>10.1</td>
<td>9.6</td>
</tr>
<tr>
<td>a</td>
<td>17.3</td>
<td>18.3</td>
<td>18.0</td>
<td>17.6</td>
</tr>
<tr>
<td>c</td>
<td>25.1</td>
<td>25.0</td>
<td>25.4</td>
<td>25.5</td>
</tr>
<tr>
<td>c</td>
<td>17.4</td>
<td>17.7</td>
<td>18.4</td>
<td>18.1</td>
</tr>
<tr>
<td>d</td>
<td>19.5</td>
<td>19.8</td>
<td>19.5</td>
<td>19.4</td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
Table II. Fabric Construction and Measurements of Knitted Woolen Hose When New and After Being Laundered with Various Detergents

<table>
<thead>
<tr>
<th>Items</th>
<th>No. of tests</th>
<th>New garment</th>
<th>Similar garments laundered 20 times in</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dtd.Water</td>
<td>Tap Water Dtd.Water Tap Water Tap Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and Soap</td>
<td>and Soap and Dreft Water and Dreft Soap, SHMP*</td>
<td></td>
</tr>
<tr>
<td>Av. Wales/in.</td>
<td>10</td>
<td>21.8</td>
<td>25.6</td>
<td>26.7</td>
</tr>
<tr>
<td>Av. Courses/in.</td>
<td>10</td>
<td>32.8</td>
<td>34.2</td>
<td>36.8</td>
</tr>
<tr>
<td>Av. Yarn Stretch (p.ct.)</td>
<td>10</td>
<td>2.0</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td>(1.5-2.6)</td>
<td>(1.6-2.3)</td>
<td>(1.5-3.0)</td>
</tr>
<tr>
<td>Ankle</td>
<td>10</td>
<td>2.1</td>
<td>2.1</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.5-2.6)</td>
<td>(1.9-2.6)</td>
<td>(1.5-2.5)</td>
</tr>
<tr>
<td>Foot</td>
<td>10</td>
<td>2.1</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.0-2.6)</td>
<td>(1.1-2.7)</td>
<td>(1.1-2.8)</td>
</tr>
<tr>
<td>Av. Wt. per Hose (gms.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New hose</td>
<td>2</td>
<td>8.2</td>
<td>8.7</td>
<td>8.7</td>
</tr>
<tr>
<td>Laundered Hose</td>
<td>2</td>
<td>7.7</td>
<td>7.7</td>
<td>7.7</td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
Table II. (Concluded) Fabric Construction and Measurements of Knitted Woolen Hose When New and After Being Laundered with Various Detergents

<table>
<thead>
<tr>
<th>Items</th>
<th>No. of tests</th>
<th>New garment</th>
<th>Dtd. Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dtd. Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Soap, SHMP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements (cm.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Hose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a to b</td>
<td>2</td>
<td>28.9</td>
<td>31.1</td>
<td>30.6</td>
<td>31.9</td>
<td>31.2</td>
<td>28.5</td>
</tr>
<tr>
<td>c &quot; d</td>
<td></td>
<td>7.7</td>
<td>7.8</td>
<td>6.9</td>
<td>7.5</td>
<td>7.7</td>
<td>7.7</td>
</tr>
<tr>
<td>e &quot; f</td>
<td></td>
<td>6.0</td>
<td>5.9</td>
<td>5.8</td>
<td>5.8</td>
<td>5.9</td>
<td>6.0</td>
</tr>
<tr>
<td>g &quot; h</td>
<td></td>
<td>5.8</td>
<td>5.7</td>
<td>5.6</td>
<td>5.8</td>
<td>5.8</td>
<td>5.9</td>
</tr>
<tr>
<td>i &quot; j</td>
<td></td>
<td>11.7</td>
<td>11.9</td>
<td>11.8</td>
<td>11.9</td>
<td>11.8</td>
<td>11.7</td>
</tr>
<tr>
<td>Laundered Hose</td>
<td>1</td>
<td>28.4</td>
<td>28.4</td>
<td>28.3</td>
<td>28.0</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td>a to b</td>
<td></td>
<td>8.1</td>
<td>7.3</td>
<td>8.3</td>
<td>8.3</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>c &quot; d</td>
<td></td>
<td>5.1</td>
<td>4.7</td>
<td>4.9</td>
<td>5.1</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>e &quot; f</td>
<td></td>
<td>4.7</td>
<td>4.6</td>
<td>4.6</td>
<td>4.7</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>g &quot; h</td>
<td></td>
<td>12.0</td>
<td>11.5</td>
<td>11.3</td>
<td>11.2</td>
<td>11.4</td>
<td></td>
</tr>
<tr>
<td>i &quot; j</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
Table III. Measurements of Strength of Knitted Woolen Garments When New and After Being Laundered With Various Detergents

<table>
<thead>
<tr>
<th>Type of Measurement</th>
<th>No. of tests</th>
<th>New garment</th>
<th>Similar garments laundered 20 times in:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dtd. Water and Soap</td>
<td>Tap Water and Soap</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHIRTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. Bursting Strength... 10</td>
<td>76.8 (64-89)</td>
<td>70.1 (60-78)</td>
<td>68.7 (55-78)</td>
</tr>
<tr>
<td>Wool and Cotton Yarn... 60</td>
<td>217.9 (130-270)</td>
<td>216.5 (128-340)</td>
<td>224.6 (160-307)</td>
</tr>
<tr>
<td>Rayon Yarn.............. 30</td>
<td>221.3 (155-280)</td>
<td>224.5 (155-245)</td>
<td>221.5 (165-250)</td>
</tr>
<tr>
<td>HOSR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. Bursting Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg (lbs./sq. in.).... 10</td>
<td>127.8 (113-146)</td>
<td>95.4 (90-118)</td>
<td>101.0 (76-112)</td>
</tr>
<tr>
<td>Foot.................... 3</td>
<td>129.8 (122-136)</td>
<td>106.8 (103-110)</td>
<td>103.8 (92-119)</td>
</tr>
<tr>
<td>Av. Yarn Tensile Str.(oz.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee.................... 10</td>
<td>16.1 (10-20)</td>
<td>15.5 (13-19)</td>
<td>13.6 (11-17)</td>
</tr>
<tr>
<td>Ankle.................... 10</td>
<td>16.5 (13-21)</td>
<td>14.0 (12-15)</td>
<td>12.1 (11-14)</td>
</tr>
<tr>
<td>Foot.................... 10</td>
<td>17.8 (14-22)</td>
<td>8.2 (7-15)</td>
<td>10.8 (6-16)</td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
Table IV. Measurements of Cleanliness of Shirts and Hose, After Being Soiled by Wearing and Laundered With Various Detergents.

<table>
<thead>
<tr>
<th>Items</th>
<th>New Garment</th>
<th>Similar Garments Laundered 20 Times in</th>
<th>Dist.Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dist.Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Tap Water and SHMPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of cleanliness, judged by observation of laundered garments.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shirts</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hose</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleanliness as measured by color analysis.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shirts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue</td>
<td>5.00Y</td>
<td>5.00Y</td>
<td>5.00Y</td>
<td>5.00Y</td>
<td>4.88Y</td>
<td>4.88Y</td>
<td></td>
</tr>
<tr>
<td>Brilliance</td>
<td>9.17</td>
<td>8.89</td>
<td>8.83</td>
<td>8.84</td>
<td>8.13</td>
<td>8.74</td>
<td></td>
</tr>
<tr>
<td>Chroma</td>
<td>3.36</td>
<td>3.87</td>
<td>4.59</td>
<td>4.05</td>
<td>3.84</td>
<td>3.66</td>
<td></td>
</tr>
<tr>
<td>Hose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue</td>
<td>5.00Y</td>
<td>4.50Y</td>
<td>4.41Y</td>
<td>3.26Y</td>
<td>2.89Y</td>
<td>4.48Y</td>
<td></td>
</tr>
<tr>
<td>Brilliance</td>
<td>8.68</td>
<td>8.56</td>
<td>8.37</td>
<td>8.20</td>
<td>7.46</td>
<td>8.26</td>
<td></td>
</tr>
<tr>
<td>Chroma</td>
<td>3.61</td>
<td>3.18</td>
<td>3.87</td>
<td>3.27</td>
<td>3.54</td>
<td>3.93</td>
<td></td>
</tr>
<tr>
<td>pH detergent solutions</td>
<td>10.19</td>
<td>9.98</td>
<td>6.30</td>
<td>8.21</td>
<td>9.79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
showed a definite loss, amounting to about ten per cent in the laundered shirts and about twenty per cent in the laundered hose. The tensile strength of the wool and cotton yarn in the shirts did not decrease except in the two cases where Dreyf was used as the detergent. In all of the laundered hose, the yarn tensile strength decreased to some extent, particularly in the foot. In considering the data as a whole, it is interesting to note that, with a few exceptions, the garments laundered with Dreyf showed a slight but consistent tendency to decrease more in strength than the others.

Table IV presents the results of two different methods of attempting to measure the degree of cleanliness obtained by laundering naturally soiled shirts and hose with various detergents. A group of four competent judges were asked to examine the laundered garments and rate them according to their degree of cleanliness. They agreed closely on the fact that the cleanest garments were those which had been laundered with soap in either distilled or tap water. The garments showing the lowest degree of cleanliness and the highest retention of soil were those laundered with Dreyf in either distilled or tap water.

To eliminate errors of personal judgment, new and laundered garments were subjected to color analysis, using the Bausch and Lomb color comparator and the standard color disks of the Munsell color system. The method employed was that of Nickerson 1/, Color Technologist, Bureau of Agricultural Economics, United States Department of Agriculture. The Munsell no-

tation has been built up around the three-dimensional idea of color, or the fact that color has three attributes: hue, brilliance, and chroma.

Hue classifies color as red, yellow, green, blue, or purple. Brilliance is lightness or darkness of a color, and consists of an 11-step scale going from zero or black to 10 or white. Chroma is the brightness or grayness of a color, zero indicating neutral gray, and each subsequent number in the scale a more intense color.

The standard color disks were slipped together and adjusted as to area until their composite color, as combined by rotating prisms, exactly matched that of the sample being tested. After measuring the exposed area of each disk, the hue, brilliance and chroma of the composite color were then computed.

When the color notations of the new and laundered garments listed in table IV are interpreted by this method, there is a definite indication that those laundered in Dreft are redder in hue, and darker in brilliance than the rest. This darker color is more pronounced in those garments laundered in tap water and Dreft, which indicates a low degree of cleanliness and agrees with the results obtained by direct observation.

It is important to note that the detergent solutions differed considerably in their pH values, those containing soap being close to pH 10, and those containing Dreft being near to the pH of the water used (Table VII).

Any differences in the effects of the various detergents on the shirts and hose may be partly attributed to the fact that the shirts contained wool, cotton, and rayon yarns, while the hose were made of wool and silk yarns.
Tables V-VIII present additional information on the laundering of wool with the various detergent solutions. Artificially soiled samples of white blankets containing various percentages of wool were laundered by a standard laboratory method and also by a home method. An additional method of determining cleanliness was introduced into this part of the experiment by determining the turbidity or the "photometric density" of each detergent solution before and after laundering the samples. A photoelectric colorimeter was used for this purpose. The galvanometer was adjusted to 100 with a tube of distilled water. When tubes containing samples of the various detergent solutions were introduced into the instrument, the galvanometer reading (G) was proportional to the amount of light transmitted. Then the quantity (2 - log G) was computed as representing the "photometric density" of the sample solution.

In table V, the photometric densities are given for each detergent solution after laundering new and soiled samples of the three types of white wool blanket. The differences between these two values have been interpreted as indicating the relative amount of material removed from the soiled samples.

With the 100 per cent wool blanket, Dreft in both distilled and tap water appeared to remove the most material, while soap with sodium hexametaphosphate in tap water was next in effect. With the 75 per cent wool blanket, soap in both distilled and tap water was the most effective in soil removal, while Dreft was least. With the 40 per cent wool blanket, the differences were not as marked.

All of these samples were analyzed for color as previously described.
and also inspected for cleanliness by direct observation. Table VI shows
that the 100 per cent wool samples laundered with Dreft in distilled water
had a slightly higher brilliance than those laundered in the other deter-
gents. This was confirmed by the judgment of the observers. However, sam-
ples laundered in tap water and Dreft always appeared to be darker in color
or less clean.

In the case of the 75 per cent wool samples, the results were the re-
verse of those previously noted, in that the greatest brilliance was found
in the samples laundered with soap, especially in tap water. This was also
confirmed by observation. The color and appearance of the laundered sam-
pies of 40 per cent wool blanket also showed that the various soap solu-
tions seemed to have removed more soil than the Dreft solutions.

Similarly soiled samples of the three types of blankets were combined
and laundered with the various detergents in a small washing machine, in
which they were subjected to more vigorous agitation and to a larger amount
of washing solution. This time, measurements of photometric density were
taken on the solutions before and after the laundering of the soiled sam-
ples. The difference between these two measurements on each solution
indicates (Table VII) that the greatest amount of material was removed from
the soiled samples laundered with soap, sodium hexametaphosphate, and tap
water. The other soap solutions were next in effectiveness, while Dreft
solutions removed the least material.

The color analysis of these laundered samples (Table VIII) shows some
agreement with the results previously presented in table VI in that the 100
per cent wool samples were cleanest and most brilliant when laundered with
Table V. Photometric Density of the Various Detergent Solutions Used in Washing Artificially Soiled Blanket Samples in a Launderometer.
(Rubber balls included in each washing process)

<table>
<thead>
<tr>
<th></th>
<th>Distilled Water</th>
<th>Tap Water</th>
<th>Dist. Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dist. Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Tap Water and Soap SHMP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo. density of original solutions.</td>
<td>0.0017</td>
<td>0.0029</td>
<td>0.1797</td>
<td>0.7680</td>
<td>0.0292</td>
<td>0.2391</td>
<td>0.7960</td>
</tr>
<tr>
<td>100 p.c.t. wool blanket</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photo. density of solns. used with New samples</td>
<td>0.0161</td>
<td>0.0099</td>
<td>1.0550</td>
<td>1.0110</td>
<td>0.1002</td>
<td>0.1643</td>
<td>1.0420</td>
</tr>
<tr>
<td>Soiled samples</td>
<td>0.0178</td>
<td>0.0243</td>
<td>1.3820</td>
<td>1.4180</td>
<td>0.6740</td>
<td>0.7615</td>
<td>1.5520</td>
</tr>
<tr>
<td>Photo. density caused by removal of material from soiled samples.</td>
<td>0.0017</td>
<td>0.0144</td>
<td>0.3270</td>
<td>0.4070</td>
<td>0.5738</td>
<td>0.5972</td>
<td>0.5100</td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
Table V. (Continued)  Photometric Density of the Various Detergent Solutions Used in Washing Artificially Soiled Blanket Samples in a Launderometer. (Rubber-balls included in each washing process)

<table>
<thead>
<tr>
<th></th>
<th>Distilled Water</th>
<th>Tap Water</th>
<th>Dist. Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dist. Water and Dref</th>
<th>Tap Water and Dref</th>
<th>Tap Water Soap SHMP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo, density of original solutions.</td>
<td>.0017</td>
<td>.0029</td>
<td>0.1797</td>
<td>0.7680</td>
<td>.0292</td>
<td>.2391</td>
<td>0.7960</td>
</tr>
</tbody>
</table>

75% Wool Blanket
Photo, density of solns, used with New Samples: | .1950 | .1357 | 0.8620 | 1.1450 | .5630 | .5435 | 1.1190 |
Soiled samples: | .2537 | .1960 | 1.2730 | 1.4830 | .8405 | .8045 | 1.5000 |

Photo, density caused by removal of material from soiled samples: | .0687 | .0603 | 0.4110 | 0.3380 | .2765 | .2610 | 0.3810 |

* Sodium Hexametaphosphate
Table V. (Concluded)  Photometric Density of the Various Detergent Solutions Used in Washing Artificially Soiled Blanket Samples in a Launderometer.
(Rubber balls included in each washing process)

<table>
<thead>
<tr>
<th></th>
<th>Distilled Water</th>
<th>Tap Water</th>
<th>Dist. Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dist. Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Tap Water and SHMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo. density of</td>
<td>.0017</td>
<td>.0029</td>
<td>.0179</td>
<td>0.7660</td>
<td>.0292</td>
<td>.2391</td>
<td>0.7960</td>
</tr>
<tr>
<td>original solutions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40% wool blanket:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photo density of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>solns. used with</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New samples</td>
<td>.2007</td>
<td>.2245</td>
<td>1.1180</td>
<td>1.3340</td>
<td>.5800</td>
<td>.4770</td>
<td>1.2490</td>
</tr>
<tr>
<td>Soiled samples</td>
<td>.2914</td>
<td>.2627</td>
<td>1.3580</td>
<td>1.5280</td>
<td>.7635</td>
<td>.7415</td>
<td>1.5557</td>
</tr>
<tr>
<td>Photo. density</td>
<td>.0907</td>
<td>.0382</td>
<td>0.2400</td>
<td>0.2490</td>
<td>.1835</td>
<td>.2645</td>
<td>0.3057</td>
</tr>
<tr>
<td>caused by removal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of material from</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>soiled samples.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate
Table VI. Measurements of Cleanliness of Wool Blanket Samples, After Being Artificially Soiled and Washed in a Launderometer with Various Detergents.  
(Cleanliness determined by color analysis)

<table>
<thead>
<tr>
<th>Blanket Samples Used</th>
<th>Samples Laundered in Distilled Water</th>
<th>Tap Water</th>
<th>Distilled Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Distilled Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Tap Water and SHMP*</th>
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<tr>
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</tr>
<tr>
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<tr>
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</tr>
<tr>
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<td>3.38Y</td>
<td>4.45Y</td>
<td>4.79Y</td>
<td>4.77Y</td>
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<td>1. Warp-cut</td>
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<tr>
<td>Hue</td>
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<td>5.00Y</td>
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<td>Chroma</td>
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<td>4.66Y</td>
<td>4.64Y</td>
<td>4.45Y</td>
<td>4.54Y</td>
<td>4.49Y</td>
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<tr>
<td>Brilliance</td>
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<td>6.69</td>
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<td>7.64</td>
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<td>2.73</td>
<td>2.91</td>
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</table>

* Sodium Hexametaphosphate
Table VI. (Continued) Measurements of Cleanliness of Wool Blanket Samples, After Being Artificially Soiled and Washed in a Launderometer with Various Detergents.
(Cleanliness determined by color analysis)

<table>
<thead>
<tr>
<th>Blanket Samples Used</th>
<th>Samples Laundered in</th>
<th>Distilled Water</th>
<th>Tap Water</th>
<th>Dist. Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dist. Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Tap Water and Dreft SHMP&lt;sup&gt;a&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>75% Wool:</td>
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<td>New</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hue  ............</td>
<td>4.58Y 4.65Y</td>
<td>4.38Y 4.36Y</td>
<td>4.16Y 4.26Y</td>
<td>4.25Y</td>
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<tr>
<td>Brilliance ..</td>
<td>8.53 8.46</td>
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<tr>
<td>Chroma ......</td>
<td>4.38 4.06</td>
<td>4.71 4.78</td>
<td>4.95 4.75</td>
<td>4.75 4.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soiled</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Warp-cut</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue  ............</td>
<td>4.14Y 4.11Y</td>
<td>4.10Y 4.23Y</td>
<td>4.52Y 4.34Y</td>
<td>4.47Y</td>
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<tr>
<td>Brilliance ..</td>
<td>6.85 6.71</td>
<td>8.58 8.43</td>
<td>8.02 7.53</td>
<td>7.53 8.29</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chroma ......</td>
<td>2.16 2.08</td>
<td>4.21 4.78</td>
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<td>3.39 4.60</td>
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</tr>
<tr>
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<td>2. Filling-cut</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Hue  ............</td>
<td>4.32Y 4.14Y</td>
<td>4.64Y 4.52Y</td>
<td>4.14Y 4.17Y</td>
<td>3.64Y</td>
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<td></td>
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</tr>
<tr>
<td>Brilliance ..</td>
<td>8.98 6.32</td>
<td>7.85 7.52</td>
<td>7.32 8.25</td>
<td>8.25</td>
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<td></td>
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</tr>
<tr>
<td>Chroma ......</td>
<td>2.37 1.89</td>
<td>4.57 4.89</td>
<td>2.70 3.06</td>
<td>3.06 4.66</td>
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</tbody>
</table>

<sup>a</sup>Sodium Hexametaphosphate
Table VI. (Concluded) Measurements of Cleanliness of Wool Blanket Samples, After Being Artificially Soiled and Washed in a Launderometer with Various Detergents.
(Cleanliness determined by color analysis)

<table>
<thead>
<tr>
<th>Blanket Samples Used</th>
<th>Distilled Water</th>
<th>Tap Water</th>
<th>Dist. Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dist. Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Tap Water and SHMP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% Wool</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue</td>
<td>4.34Y</td>
<td>4.04Y</td>
<td>3.16Y</td>
<td>3.42Y</td>
<td>3.44Y</td>
<td>3.53Y</td>
<td>3.70Y</td>
</tr>
<tr>
<td>Brilliance</td>
<td>8.47</td>
<td>8.32</td>
<td>8.87</td>
<td>8.51</td>
<td>8.29</td>
<td>8.35</td>
<td>8.18</td>
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<tr>
<td>Chroma</td>
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<td>2.91</td>
<td>3.08</td>
<td>3.19</td>
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<td>3.11</td>
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<td></td>
</tr>
<tr>
<td>1. Warp-cut</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue</td>
<td>3.17Y</td>
<td>3.17Y</td>
<td>3.79Y</td>
<td>3.59Y</td>
<td>3.59Y</td>
<td>3.59Y</td>
<td>3.70Y</td>
</tr>
<tr>
<td>Brilliance</td>
<td>7.66</td>
<td>7.32</td>
<td>8.84</td>
<td>8.47</td>
<td>7.99</td>
<td>7.79</td>
<td>8.22</td>
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<tr>
<td>Chroma</td>
<td>1.83</td>
<td>1.83</td>
<td>2.70</td>
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<td>2.34</td>
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<td>2. Filling-cut</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hue</td>
<td>3.00Y</td>
<td>3.00Y</td>
<td>3.63Y</td>
<td>3.63Y</td>
<td>3.65Y</td>
<td>3.65Y</td>
<td>3.63Y</td>
</tr>
<tr>
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<td>7.09</td>
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<td>8.38</td>
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<tr>
<td>Chroma</td>
<td>1.68</td>
<td>1.68</td>
<td>2.40</td>
<td>2.40</td>
<td>2.40</td>
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</tbody>
</table>

* Sodium Hexametaphosphate
<table>
<thead>
<tr>
<th></th>
<th>Distilled Water</th>
<th>Tap Water</th>
<th>Dist. Water and Soap</th>
<th>Tap Water and Soap</th>
<th>Dist. Water and Dreft</th>
<th>Tap Water and Dreft</th>
<th>Tap Water and Soap SHMP*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Photo. density of original solutions</strong></td>
<td>.0000</td>
<td>.0013</td>
<td>.0204</td>
<td>.4365</td>
<td>.0055</td>
<td>.0093</td>
<td>.3290</td>
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<tr>
<td><strong>Photo. density of detergents after laundering soiled samples</strong></td>
<td>----</td>
<td>----</td>
<td>.1964</td>
<td>.6240</td>
<td>.1010</td>
<td>.1107</td>
<td>.5710</td>
</tr>
<tr>
<td><strong>Photo. density of solutions caused by material removed from soiled samples</strong></td>
<td>----</td>
<td>----</td>
<td>.1760</td>
<td>.1875</td>
<td>.0955</td>
<td>.1014</td>
<td>.2420</td>
</tr>
<tr>
<td><strong>pH of original solutions</strong></td>
<td>5.98</td>
<td>8.21</td>
<td>10.23</td>
<td>9.92</td>
<td>7.23</td>
<td>8.22</td>
<td>9.70</td>
</tr>
</tbody>
</table>

*Sodium Hexametaphosphate
Table VIII. Measurements of Cleanliness of Wool Blanket Samples, After Being Artificially Soiled and Laundered in a Washing Machine With Various Detergents. (Cleanliness determined by color analysis)

<table>
<thead>
<tr>
<th>Blanket Samples Used</th>
<th>New Samples</th>
<th>Soiled Samples</th>
<th>Dist. Water Soap</th>
<th>Tap Water Soap</th>
<th>Dist. Water Dreft</th>
<th>Tap Water Dreft</th>
<th>Tap Water Soap</th>
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<tbody>
<tr>
<td>100% Wool</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue</td>
<td>3.73Y</td>
<td>3.87Y</td>
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<td>4.59Y</td>
<td>4.48Y</td>
<td>4.50Y</td>
<td>4.57Y</td>
</tr>
<tr>
<td>Brilliance</td>
<td>8.17</td>
<td>6.50</td>
<td>8.07</td>
<td>7.96</td>
<td>8.23</td>
<td>8.14</td>
<td>7.91</td>
</tr>
<tr>
<td>Chroma</td>
<td>4.21</td>
<td>1.44</td>
<td>3.33</td>
<td>3.23</td>
<td>3.99</td>
<td>3.45</td>
<td>3.15</td>
</tr>
<tr>
<td>75% Wool</td>
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<td></td>
</tr>
<tr>
<td>Hue</td>
<td>3.73Y</td>
<td>3.83Y</td>
<td>4.63Y</td>
<td>4.63Y</td>
<td>4.1Y</td>
<td>4.18Y</td>
<td>4.63Y</td>
</tr>
<tr>
<td>Brilliance</td>
<td>7.60</td>
<td>6.50</td>
<td>7.82</td>
<td>7.82</td>
<td>7.36</td>
<td>7.31</td>
<td>7.32</td>
</tr>
<tr>
<td>Chroma</td>
<td>3.84</td>
<td>1.59</td>
<td>3.66</td>
<td>3.66</td>
<td>2.34</td>
<td>2.82</td>
<td>3.66</td>
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<tr>
<td>40% Wool</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue</td>
<td>2.29Y</td>
<td>3.79Y</td>
<td>4.49Y</td>
<td>4.49Y</td>
<td>3.95Y</td>
<td>3.34Y</td>
<td>4.49Y</td>
</tr>
<tr>
<td>Brilliance</td>
<td>7.66</td>
<td>6.74</td>
<td>8.07</td>
<td>7.96</td>
<td>7.82</td>
<td>7.72</td>
<td>8.01</td>
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<td>1.26</td>
<td>2.70</td>
<td>2.70</td>
<td>2.19</td>
<td>2.28</td>
<td>2.70</td>
</tr>
</tbody>
</table>

* Sodium Hexametaphosphate.
Dreft; the 75 per cent samples were cleanest with soap solutions; and the 40 per cent wool samples showed little difference in the cleanliness produced by all the detergent solutions.

From all of these data it would seem that Dreft is slightly more efficient than soap in the cleansing of all-wool fabrics, such as the 100 per cent wool blanket. However, when fabrics are composed of wool yarns in combination with cotton or other fibers, soap appears to be a more efficient detergent than Dreft. This was demonstrated by the results obtained from laundering both artificially soiled part-wool blankets and naturally soiled part-wool infants' garments.

In general, distilled or soft water produced a higher degree of cleanliness with each detergent than did tap or hard water, with the same detergent. This can easily be explained in the case of soap and hard water, where the calcium and magnesium curd is formed and clings to the fabric. Although, theoretically, Dreft does not react chemically with the calcium and magnesium compounds in hard water, there was a certain amount of turbidity or cloudiness when Dreft was dissolved in tap water.

The addition of sodium hexametaphosphate (21) to hard water is supposed to bind the calcium and magnesium salts in an insoluble form so that when soap is added, there is absolutely no precipitation. For some reason, the sodium hexametaphosphate did not entirely prevent precipitation in these laundering tests. The turbidity produced by it had a chalky white color as compared with the bluish hue of the soap curd.

A thorough review of the literature on this subject shows that very few studies have been made for the purpose of comparing the relative deter-
gent properties of soap and non-soap detergents, such as Dreft. Lucy (33) recently carried on some laboratory detergency tests to show the effect of varying conditions on detergent action. He found that increasing the agitation seemed to improve the detergency, which would coincide with the results obtained in this study when the soiled samples were laundered in a washing machine instead of a launderometer.

Lucy also reported that sodium lauryl sulfate (Dreft) worked most rapidly in its cleaning action at 150-200 C. However, this temperature is lower than that recommended for the laundering of wool. He found that the use of a small percentage of soda ash with Dreft made it more efficient as a detergent. That policy was not followed in this experiment because it was preferred to study the effect of Dreft alone. Lucy concluded his work with the statement that "in the present state of the theory of detergency, direct laboratory test of the cleaning efficiency of various agents is more satisfactory than prediction of results from theoretical grounds".
SUMMARY AND CONCLUSIONS

1. Three laundering methods were used to compare the effect of soap and non-soap detergents in cleansing wool fabrics in hard and soft water.

2. In the first method, five sets of infants' garments were soiled by actual wear and laundered twenty times each in a small hand-washer. A specific detergent solution was used for each set: soap and distilled water, soap and tap water, Dreft (a non-soap detergent) and distilled water, Dreft and tap water, and soap in tap water softened by sodium hexametaphosphate.

3. In the second method, five sets of samples from three white wool blankets containing various percentages of wool were soiled by a standard soiling solution and washed in a launderometer, using the same detergent solutions as above.

4. In the third method, five sets of samples from the same white wool blankets were artificially soiled and laundered in a small washing machine which contained a larger amount of detergent solution and provided more agitation.

5. In the laundering of soiled all-wool fabrics, Dreft, in either soft or hard water, appeared to be a more efficient detergent than soap.

6. In the laundering of soiled part-wool fabrics, soap, in either soft or hard water, appeared to be a more efficient detergent than Dreft.

7. When each detergent was dissolved in distilled or soft water, it seemed to have a more cleansing effect on the fabrics than when the same detergent was dissolved in tap or hard water, even when an effort was made to soften the hard water.
Larger amounts of detergent solution and increased agitation seemed to improve the cleansing power of all the detergent solutions.
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