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I Halogen as a finish for wool II Formaldehyde as a finish for wool III Comparison of three textile detergents

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I. HALOGEN AS A FINISH FOR WOOL

II. FORMALDEHYDE AS A FINISH FOR WOOL

III. COMPARISON OF THREE TEXTILE DETERGENTS

by

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INTRODUCTION

The first two studies were undertaken in order to obtain quantitative data for the stability of the modified keratins, chlorinated wool and formaldehyde-treated wool.

The third study was made to compare the effects of soap, silicated soap, and a sulfated alcohol in the washing of plain-woven cotton, regenerated-cellulose rayon, cellulose-acetate rayon, silk, wild silk, and wool.

I. HALOGEN AS A FINISH FOR WOOL

REVIEW OF THE LITERATURE

<u>Chlorination of wool with elemental chlorine or inorganic derivative of chlorine</u>

1839 John Mercer at Fort Brothers and Company in England, while seeking ways of increasing the affinity of wool for dye, notices that wool absorbs 35 percent of chlorine and becomes yellow and of increased affinity for dye when immersed in two to five percent solutions of bleaching powder (63, 174).

1865 Lightfoot introduces chlorination as British Patent 2327, a pretreatment for wool to be printed Aniline Black (110, 129). He later describes chlorinating one kilogram of wool for twenty to thirty minutes at 38°C. in ten liters of an aqueous solution of one kilogram of bleaching powder (141).

1867 Schützenberger points out that chlorine and hypochlorite alter wool in coloring it yellow (202).

1868 Behrens recommends a forty-volume bath of hydrochloric acid (12.5 grams of concentrated hydrochloric acid per liter of water) as a pretreatment for chlorination and records the ratio of wool to bleaching powder required for diminishing shrinkage as ten, that for producing complete unshrinkability as five, and ratios of 3.3 and 2.5 as usable (20).

1870 Calvert observes that carbon dioxide and nitrogen (7.81 percent) are evolved when wool is treated with hypochlorite (31). At this time Havrez finds that chlorinated wool may be heavily mordanted with chrome alum without any noticeable decomposition (140).

1882 Persoz (177) and Witz (271) study the chlorination of wool which the latter describes as greatly increasing the affinity of wool for dye.

1885 Lunge patents the use of hydrogen peroxide for decolorizing chlorinated wool (146).

1888 Witt calls attention to the scroop of chlorinated wool and to him has been attributed the statement that chlorinated wool dissolves in ammonia with evolution of nitrogen, a statement Grandmougin could not confirm (79).

1891 Lake patents a process for improving the printing of Aniline Black on wool by means of pretreatment with six to ten percent bleaching powder acidified with hydrochloric acid (138). Justin-Mueller oxidizes wool with sodium chlorate before printing it with dye (119, 120).

1892 Knecht and Milnes note that dry chlorine has no effect on wool but that moist chlorine brings about the evolution of hydrogen chloride and leaves a residue which loses more than sixty percent in weight and becomes gummy and translucent when boiled in water. They consider that chlorinated wool is slightly oxidized but contains no chlorine (130, 131, 132). Lodge describes the great increase in wool's affinity for acid and mordant dyes brought about during thirty minutes' treatment in a two to 2.5 percent solution of bleaching powder acidified with sulfuric acid (143).

1894 Bulard studies wool's absorption of chlorine from a hypochlorite and emphasizes the rapidity of this action and the harsh handle of the residual wool (28). Grandmougin includes a recipe for chlorinating wool in his review of progress in dyeing (78). Kopp observes that wool creped with zinc sulfate suffers less degradation during chlorination (134).

1895 Leuzen (139) and Hummel and Gardner (110) investigate the dyeing and mordanting of chlorinated wool; the latter state that treatment of wool with hypochlorous acid has no effect upon its subsequent mordanting with salts of chromium.

1896 Stobbe calls attention to the luster of chlorinated wool by naming it Seidenwolle (220). Clad and Company propose the use of stannous chloride for decolorizing chlorinated wool (43, 227).

1897 Imray patents a process for chlorinating wool by treatment of a kilogram of dry wool in constant motion with 25 liters of dry chlorine in a gas-tight tank; he describes the product as whiter than that prepared by moist treatment, translucent, scroopy, and of increased affinity for dye and decreased felting power (113). Two more patents dealing with chlorination of wool appear at this time (47, 60). Knecht proposes two-minute printing of chlorinating agent before milling for the production of permanent crepe from *mousseline de laine* (127,128). Thiele notices that sulfur dioxide does not decolorize chlorinated wool and that the latter shows fewer scales than wool does (226). Stobbe reports an eight to ten percent loss in weight by wool during chlorination (221).

1898 Pitt and Leopold Cassella and Company patent a process for producing two-color wool crepes by milling fabric of wool yarns and chlorinated-wool yarns in acid before dyeing (33, 179). Platt recalls *Seidenwolle* was first prepared on a practical scale in 1894 (180). Prud'homme offers a recipe for chlorination of wool in his consideration of its dyeing and structure (182). Grandmougin uses salts of tin as well as chlorination in the production of wool crepes (77).

1899 Florin and Lagache state in a patent that inorganic salts or weak acids restore to chlorinated wool all the properties of wool except unshrinkability (67). Melher proposes chlorination for production of scroop as well as silky luster on wool (156).

1900 Gillet considers that the principal change effected in wool by chlorination is greater ease of wetting (75).

1901 Koechlin chlorinates wool in preparation for its printing (133).

1905 Bethmann patents a process for chlorinating wool to be dyed Aniline Black (22).

1906 Grandmougin reports that the yellow color of chlorinated wool is lessened by light or reductant, that there is no loss of nitrogen during chlorination, and that chlorinated wool withstands several hours' boiling (79). Vignon and Mollard study the effect on wool of gaseous chlorine (dry and moist at room temperature and at 50°C.), neutral, acid, and alkaline chlorine water, acidified solution of bleaching powder, and the last followed by an antichloring bath of sodium hydrogen sulfite. They observe that the greatest loss of weight occurs in an alkaline solution of chlorine, the least in an acid solution which, however, lowers wool's strength and elasticity most; these latter properties Vignon and Mollard find a neutral solution of chlorine changes least (261, 262, 263, 264).

1908 Baudisch notes that chlorinated wool, contrasted with wool, loses no sulfur as sulfur dioxide during treatment with sirupy phosphoric acid and he suggests that chlorination attacks the sulfur of keratin (19). Kertesz maintains in a controversy with Kapff that bleaching powder lowers the strength and elasticity of wool so much that chlorinated wool deteriorates during subsequent dyeing (123).

1909 A patent (190) and some descriptions of chlorinated wool bear this date (34, 176, 258).

1911 Lumpp patents a method for making wool unshrinkable by treating it in the presence of an aldehyde with a hypochlorite neutralized by an organic acid (145).

1913 Samuel cautions against energetic soaping of wool after chlorination (197).

1914 Hepburn patents a method for the production of color on wool, the immersion of wool first in hypochlorous acid and then in a bath containing an amino compound (100).

1915 Garrett patents a process for producing unshrinkable wool, treatment of wool with a bath of chlorine followed by a dilute bath of ammonia and soap(74).

1916 A substance between the external plate cells and the fibrous cells of wool is named elasticum by von Allwörden who describes it as soluble in alkali and forming an osazone. He suggests testing wool by microscopic examination of the fiber in chlorine water which does not attack the scales but readily attacks the fibrous cells and swells the <u>elasticum</u> to globular enlargements which distend the scales. The durability of a wool fabric, according to von Allwörden, is greatly impaired by removal of <u>elasticum</u> (3, 4, 137). Naumann (171), Krais and Waentig (135, 136), and others (11, 167, 168, 184, 217) later find that different kinds of wool and different sections of a single staple behave variously in this test.

1921 Schweitzer patents a process for chlorinating wool fabric before waterproofing it (203). In another patent he describes the chlorination of pig bristles to soften them and increase their luster and affinity for dye (204).

1922 Trotman reports a gradual solution of nitrogen and sulfur from wool and a change in the residual wool's ratio of nitrogen to sulfur with increasing time or temperature of chlorination. He finds that a wool yarn, 3.74 percent sulfur and 16.01 percent nitrogen, analyzes as 3.29 percent sulfur and 15.57 percent nitrogen after treatment with chlorine water (five grams per liter) and that wool treated with hypochlorous acid (two or three grams per liter) loses, respectively, but 2.6 or three percent in weight while wool treated with chlorine water (three grams per liter) loses 15.6 percent in weight. Trotman also reports that chlorinated wool is not, although over-chlorinated wool is, more soluble than wool in water, dilute acetic acid, 0.1 N sodium carbonate, or 0.1 N sodium hydroxide. He describes a good sample of chlorinated wool as containing no more than a trace of chlorine, as of lower strength and elasticity than wool but of no more than five percent of damaged fibers, as of slightly greater affinity than wool for dye, and as of slight solubility (3.5 to 4.1 percent in three hours) in tenth normal alkali (231).

1923 Adams observes that chlorination with bleaching powder has no marked effect on wool's affinity for dye (1). Friedel proposes the printing of sodium hypochlorite acidified with hydrochloric acid for the production of two-colored wool crepes (71). Meunier and Latreille study the effect of dry gaseous chlorine on dry and moist wool and find that dry wool, three percent sulfur, after treatment with chlorine in carbon tetrachloride contains 2.08 percent of sulfur and 4.4 percent of chlorine. They suggest that chlorine forms chloroamines with wool and that loss in weight during wet chlorination is due to oxidation. They show that wool shrinks less during dry chlorination and that either dry or wet chlorination facilitates the fixation of certain dyes (161). Nanson proposes chlorination as a means of scrooping wool (170). Trotman and Langsdale show that wool damaged by ozone has properties similar to those of chlorinated wool and that chlorinated wool is more readily attacked than wool by ozone (243). Trotman proposes a chlorinating bath containing 0.6 gram of available chlorine per liter (237) and stresses the cumulative damage chlorinated wool undergoes during further processing (235).

1924 Trotman and Wyche observe that wool and deaminated wool exhibit the same shrinkage, elasticity, and strength and absorb the same amount of chlorine (248). Trotman and Trotman patent a method for chlorinating wool with hypochlorous acid produced either by passing gaseous chlorine into water containing calcium carbonate or sodium hydrogen carbonate or by adding boric acid to bleaching powder (244).

1925 Trotman patents a process for producing unshrinkable wool, treatment of wool for thirty to 45 minutes with hypochlorous acid, 0.5 percent available chlorine per weight of wool (238).

1926 Spagnol notices that wool exposed five minutes to gaseous chlorine shows an intense iodine-starch coloration after thirty days' airing (214). Speakman and Goodings study the chlorination of wool microscopically and observe no drastic change in the wool fiber with either chlorine or hypochlorous acid. They attribute the low durability of alkaline-treated chlorinated wool to the formation of a gelatinous layer between cortex and cuticle and recommend mordanting with dichromate to increase durability. They consider uniform chlorination well nigh impossible because of chlorine's preferential absorption by outer fibers (215, 216). Trotman and Trotman are unable to correlate shrinkage and damage to scales; they ascribe felting to the epithelial cells and shrinkage to the cortex and note that treatment with hypochlorous acid results in no damage until the chlorine absorbed attains four percent by weight of the wool, that wool's affinity for dye is unchanged, and that chlorine, but not hypochlorous acid, produces chloroamines (245, 246). Some reviews of chlorinated wool are published (41, 147).

1927 Böhm patents nascent chlorine for the chlorination of wool (25, 26) and chlorate for the oxidation of animal fibers to be milled (24, 150). Campbell reviews the chlorination of wool (32). Fleming claims that chlorinated wool should show no more than ten percent of damaged fibers, no more than a trace of chloride, and no marked increase in affinity for acid dye and that no more than five percent of it should dissolve in tenth normal sodium carbonate (65, 66). Hall measures degree of damage upon chlorination by means of chlorinated wool's solubility in tenth normal sodium hydroxide and observes that wool treated with five, 25, and fifty percent of chlorine per weight of wool loses, respectively, 3.51, 9.00, and 14.5 percent in weight. He recommends mordanting chlorinated wool with sodium dichromate as a protective measure (85).

1928 Barritt reports that the total nitrogen of wool is reduced from 16.53 to 16.30 percent (in terms of chlorinated wool) during thirty minutes in 1.113 percent chlorine water (17). Ernotte points out that the amount of chlorine to be used in chlorinating wool depends on the structures of fiber, yarn, and fabric and recommends after-treatment of chlorinated cortex with dichromate (58). Herzog describes microscopically visible changes in the three radial layers of over-chlorinated wool, the epidermis, the outer chlorinated cortex, and the inner unchlorinated cortex (103). Trotman, Trotman, and Brown note that wool loses no nitrogen during treatment with hypochlorous acid (0.5 percent chlorine per weight of wool) for thirty minutes and that the residual wool does not combine with semicarbazide (247). Meissner (155), Sansone (199), and Schofield (201) describe methods for chlorinating wool. Sykes suggests that chlorinated wool be dyed at a lower temperature than wool, 30 or 40°C. (223).

1929 Barritt and King find that wool loses 28.1 percent of its sulfur during one hour's treatment with chlorine (31.2 percent per weight of wool) (18). Dreyfus patents the use of hypochlorite in an acid medium for chlorinating wool in the presence of cellulose-acetate rayon(52).

Salomone states that chlorination at a pH of 4.8 results in in minimal degradation (196).

1930 Craveri describes the greater luster and mechanical strength of chlorinated wool (49) and Robert (188) and Trotman (232, 236) review its chlorination. Sachs ascribes the increased glossiness of chlorinated wool to its lack of scales (193, 194, 195). Smith and Ruby patent the use of a buffer in the chlorinating bath of alkali hypochlorite (209).

1931 Meunier finds that prolonged dry chlorination of wool followed by rinsing produces the same effect as wet chlorination and that wool undergoes no change when treated with dry chlorine for longer than necessary to effect unshrinkability (160). Russina considers the wet strength of wool much more characteristic than its dry strength (191). Trotman proposes these standards for chlorinated-wool fabric: a) damaged fibers (microscopically detected) shall not exceed twenty percent, b) tensile strength and elasticity shall not be impaired, c) shrinkage shall not exceed ten percent and the fabric shall not felt upon washing, d) color shall be good or respond readily to bleaching, e) handle shall not be harsh, and f) durability shall be at least 75 percent of the untreated fabric. The percentage of chlorinated wool's nitrogen that dissolves in tenth normal sodium carbonate is also suggested by Trotman as a measure of this keratin's degree of stability (234).

1932 Phenols are described as better than formaldehyde for protecting wool during chlorination (102). Chlorination is proposed for lustering wool yarns (225) and shrinking hosiery (39). Edwards measures the absorption of chlorine in 45 minutes by five grams of wool from 500 milliliters of acidified sodium hypochlorite and finds the absorption of chlorine proportional to its concentration and to duration of treatment. He observes that wool treated with 500 milliliters of a solution, 2.75 percent available chlorine, absorbs 32 percent of the total chlorine in five minutes and 59 percent in 45 minutes and that the chlorine absorbed is inversely proportional to the volume of the solution (55). Processes for chlorinating wool (149, 165) and dyeing silk and chlorinated wool in mixed fabrics (187) are published.

1933 Clark suggests the use of bleaching powder or sodium hypochlorite for lustering and softening the colors of wool carpet (45, 46). Edwards states that a wool which absorbs two percent of chlorine should be processed in a bath containing three percent of chlorine and that milling has no effect on wool's behavior during chlorination (53, 54, 56). Hirst and King investigate the use of chlorine, bleaching powder, and hypochlorous acid, in neutral and acid solutions with and without salt, as to degree of unshrinkability, strength, color, and handle of the residual wool. They note that a greater concentration of chlorine may be used with salt without causing undue loss of strength (104). Merkel and Kienlin G.m.b.H. patent chlorination as pretreatment in the waterproofing of wool (158). Trotman investigates the action of bromine and of chlorine on knitted wool in neutral and acid solutions and in the presence of salts. He finds that the 2.8 percent of chlorine absorbed from three percent neutral chlorine water produces negligible damage but that the same absorption from acidified chlorine water results in 28 percent of damage. He notes, too, that more damage occurs at 60° than at 37.8°C. (233, 239). Velitchkoiwitch recommends a temperature of 55°C. for dyeing mixed fabrics of silk and chlorinated wool (259). Weber proposes that wool hosiery be chlorinated before it is bleached with hydrogen peroxide (266). Two other descriptions of chlorinated wool appear (51, 70).

1934 Chlorinated wool's increased affinity for dye is ascribed by vom Hove to oxidative degradation of its outer layer (106, 107, 108). Mild chlorination is patented as a pretreatment for the production of insoluble azo dyes on wool (212) and on mixed fabrics of wool and regenerated cellulose (111, 112). The chlorination of wool before its waterproofing with a salt of aluminum is patented (157). Bleaching of wool with hydrogen peroxide is described as preferable before chlorination and bleaching with sulfur dioxide after chlorination (249). Chlorination is decried as expensive amd destructive to handle and durability (181). A review of chlorination emphasizes that damage shows up more clearly when wool is wet (268). Sobue and Hirano report that 2.25 and 5.47 percent of a wool dissolve in one hour at 25°C. in calcium hypochlorite corresponding, respectively, to 0.0032 and 0.0917<u>N</u> hypochlorous acid (211). Trotman, Bell, and Saunderson propose the absorption of acid dye by residual wool as an index of degradation during chlorination (242). King (124), Sansone (198), and Viertel (260) write about the chlorination of wool. Wool Industries Research Association, King, and Galley (272) of Leeds, England develop an apparatus and method for treating wool with one pound of gaseous chlorine or bromine per ten cubic feet of tank for one hour:

> "The treating chamber is substantially evacuated by exhaust pump after inserting the material to be treated and before admitting chlorine or bromine, so that the latter is almost instantaneously diffused through a perforated tube embedded in the sliver, yarn, or fabric which can be packed very closely and wound tightly around the diffuser" (253).

The wool is removed, thoroughly washed with water, and antichlored with sodium hydrogen sulfite. The chlorinated product is said to be of enhanced spinning property, no fulling property, and for a given yarn number the yarn spun from staple so treated is of thirty to fifty percent greater strength than that spun from the untreated wool (44). Meunier at once points out that dry chlorination of wool has been used in France since Latreille's work of 1923 (159).

1935 Courtot and Baron record that long exposure of wool to chlorine or bromine in water causes solution of sixty percent of the wool (48). Trombar describes the chlorination of wool preceding its printing with acid, chrome, or substantive dyes (230). Trotman and Bell list the principal causes for uneven dyeing of chlorinated wool with acid dye as uneven chlorination and the great affinity of chlorinated wool for dye at a low temperature (240). Bleaching powder is patented as a means of making wool unshrinkable (73). Nakahara and Tanaka observe that when wool is chlorinated with either calcium or sodium hypochlorite the amount of chlorine absorbed and the damage, measured by loss of weight and strength, increases with increasing concentration, temperature, and time of treatment. They report that a greater loss of weight occurs with calcium hypochlorite than with sodium hypochlorite but that the latter lowers the strength more (169). Utaka expresses the mechanism of the chlorination of wool as,

$$X = K\ T^{M}$$

where X is the product after T hours and K and M are constants. Utaka notes that chlorination is slower in diffused than in direct light (257).

1936 Chlorination is described for the production of antique finish on wool carpet (7) and for luster (267). Chlorination is attacked as impoverishing wool, producing cloudiness after washing, and, although not always producing unshrinkability, as adversely affecting "shape retention" of fabric when absolute unshrinkability does result (250). Foulon contrasts the permanent shrinkage of wool by chlorine with the temporary shrinkage produced by aluminum or chromium sulfate (69). Hall, Hicking, and Pentecost patent the production of unshrinkable wool by treating air-dry wool for one hour at 40°C. with the vapor, solution, or dispersion (1.5 to 2.5 percent by volume) in an inert organic solvent (naphtha, carbon tetrachloride, trichloroethylene, or diethyl ether) of a derivative of sulfur hydrolyzable to hydrochloric or sulfuric acid (fuming sulfuric acid, chlorsulfonic acid, sulfuryl chloride, thionyl chloride, sulfur monochloride, sulfur dichloride, or sulfur trioxide). The residual wool is centrifuged, washed in water, neutralized in warm dilute alkali, rinsed in water, and dried (86, 89, 90, 91, 92). Hall later states that the effect of sulfuryl chloride on the felting property of wool as measured by reduced shrinkage upon washing depends on the a) concentration of sulfuryl chloride, b) ratio of volume of sulfuryl chloride to weight of wool, c) temperature, d) duration of treatment, and e) original content of moisture in the wool (83). This Dri-Sol process is further described by Hall (81, 82, 84, 87, 88) and others (27, 40, 80, 114, 148, 154, 172, 229, 252, 254, 274). The fiber is said not to be changed appreciably in diameter, length, handle, luster or affinity for dye and its protective sheath of epithelial scales and its milling property remain intact. The uniform, thorough penetration and slow action achieved in this process result in the same shrinkage for wool treated with 2.5 percent sulfuryl chloride as for wool treated with 4.5 percent chlorine and the former's solubility in alkali is 2.5 times less. Sulfuryl chloride is further described as of no effect on dry cotton or viscose yarn and on most wool dyes and direct cotton dyes (256). Meissner develops a color test for chlorinated wool (153). Jordan (116) and Wilsome (270) give recipes for chlorinating wool with hypochlorites.

1937 Justin-Mueller describes hypochlorites and chlorine as bringing about the elimination of wool's labile sulfur (117, 118, 122). Smith and Harris chlorinate wool with sodium hypochlorite, eight percent active chlorine per weight of wool, at a pH of eight and observe that its affinity for acid is decreased and that, although its rate of adsorption of dye increases, its total adsorption of dye is lower than that of wool (207). Wool fabrics made unshrinkable by sodium hypochlorite are described (255). Rordorf develops a process in which an organic derivative of chlorine is added to a hypochlorite for chlorinating wool (189). Fischer considers this Hypak process better than the Dri-Sol process (64).

1938 Amino and imino compounds are patented for controlling the chlorination of wool with hypochlorites (35, 269). Justin-Mueller recommends the chlorination of wool before printing because resists on untreated wool show halos (121). Wool Industries Research Association, Phillips, and Carter patent shrink-resisting treatments for wool which use bromine or chlorine with sulfur dioxide or other volatile compounds hydrolyzable to acid (273). Henk describes an acid reaction as favoring the type of chlorination desirable for making wool unshrinkable and a neutral reaction as better for oxidation and improvement of wool's affinity for dye (99). The Dri-Sol process is said to be less destructive than aqueous chlorination (178, 189, 210).

1939 Lindenmaier maintains that chlorination is being exploited in the production of unshrinkable wool (142). Some reviews of the chlorination of wool are published (57, 72, 95, 115, 185).

Chlorine and bromine have also been proposed for the tanning of hides (144, 162, 163, 164, 166).

Chlorination of wool with organic derivatives of chlorine

Organic derivatives of chlorine which have been suggested for chlorinating wool are the *N*-chloroamides of aromatic sulfonic acids and the alkyl hypohalites.

1926 Wagener describes the use of *Aktivin* or *Chloramine-T*, $p\text{-}CH_3C_6H_4\overset{O}{\underset{N-Cl}{S}}\text{-}ONa$, for chlorinating wool which is to be printed (265).

1928 According to Armour wool is first treated with a cold solution of acetic, formic, or hydrochloric acid, then with a cold solution, one percent by volume of *Aktivin* for ten minutes, washed, and antichlored with hydrogen peroxide; the product is said to be of enhanced luster and affinity for dye and of diminished felting and shrinking properties (8).

1929 Feibelmann states *Aktivin* attacks wool less vigorously than hypochlorous acid does and he attributes the more nearly uniform chlorination to slower absorption of chlorine (62). Other articles which deal with the application of *Aktivin* to wool are published (42, 126, 183, 206, 224).

1930 Chemische Fabrik Pyrgos G.m.b.H. and Feibelmann patent the use of various N-dichloroaromatic sulfonamides such as Peractivin or Dichloroamine-T, $p\text{-}CH_3C_6H_4SO_2NCl_2$, for the chlorination of wool (36, 38, 61).

1938 The use of an aqueous solution containing both Peractivin and an inorganic hypohalite is patented for the chlorination of wool (37).

In this same year Jackson patents a method for making wool unshrinkable by the action of tert-butyl or amyl hypochlorite (114).

Bromination of wool

1892 Schoen observes that the action of bromine on wool is like that of chlorine (200).

1895 The treating of wool with bromates before printing it with dye is patented (59).

1898 Koethe states that a solution of bromine, five to 7.5 percent of wool's weight, in thirty minutes at 30 to 35°C. does not yellow wool as chlorine does and produces less luster (29).

1914 Ross and Callan use bromine to produce wool of good handle and unshrinkability (30).

1917 Aiello studies the effect of bromine on rabbit hair and notes that this hair becomes brittle after a few hours (2).

1919 Herbig describes the action of bromine as more pronounced than that of chlorine in the von Allwörden reaction (101).

1925 Stary treats human hair with bromine dissolved in acetic acid and obtains a product containing more oxygen and readily soluble in alkali (218).

1934 The WIRA process (272, 273) and vom Hove's work include bromination (106, 107, 108).

1935 Trotman and Bell study the use of aqueous solutions of bromine for the production of unshrinkable finish on knitted wool and conclude that bromine neither appreciably lowers the strength nor changes the absorbency of wool (240, 241). Stirm and Collé assign the cause of the von Allwörden reaction to the solution of wool's cystine and tyrosine; they report that 27 percent of the total cystine and 34 percent of the total tyrosine dissolve from wool treated with bromine water while but 1.91 percent of the total cystine goes into solution when wool is treated with chlorine water (219).

1936 Alkaline hypobromite is patented for reducing the affinity of protein for neutral and acid dyes (213).

1939 Henk describes the more costly bromination as less destructive than chlorination for wool and its product as more stable (98).

<u>Iodination of wool</u>

1922 Huebner and Sinha record the formation of iodoform in the steam distillation of wool with iodine and sodium hydroxide (109).

1930 Haller reports iodine quantitatively reduced by wool and this reducing action of wool as in no way connected with its sulfur (93).

1934 Assuming that iodine adds at the free amino groups of wool keratin, and correcting for an unknown quantity of cysteine which might be present, Harris, Neville, and Fritz obtain values ranging between 8.3 and 9.4 for the "iodine number" of wool. They propose the use of this determination as a measure of wool's chemical degradation (96, 97). McKay labels this "iodine number" empirical and states that it cannot be explained on the basis of a reaction between iodine and the free amino groups of wool (151).

1936 Haller and Holl report that wool absorbs iodine for fifteen hours after immersion in solutions containing 1.9 to 12.9 grams of iodine per liter but that only part of the iodine is chemically combined. They find that the absorbed iodine, removable with boiling water, varies with the concentration of the solution although the combined iodine remains constant at 6.5 percent. They also observe that, although wool readily absorbs and combines with iodine dissolved in water or ethanol, it does so to a less extent from solution in chloroform, and least from solutions in benzene, toluene, or carbon disulfide (94, 251).

EXPERIMENTAL PROCEDURE

Materials

1. Ammonium nitrate. C. P. General Chemical Company.

2. Ammonium vanadate. C. P. General Chemical Company.

3. Arsenious oxide. Purity 99.8 percent. General Chemical Company.

4. Asbestos. Long fiber. General Chemical Company.

5. Barium chloride. C. P. General Chemical Company.

6. Benedict-Denis reagent. Twenty-five grams of cupric nitrate, $Cu(NO_3)_2 \cdot 3H_2O$, 25 grams of sodium chloride, and ten gram of ammonium nitrate were made up to 100 milliliters with water (50).

7. Benzoic acid. Reagent. General Chemical Company.

8. Bleaching powder. Perchloron. Pennsylvania Salt Manufacturing company.

9. Boric acid. C. P. General Chemical Company.

10. Cupric nitrate. C. P. General Chemical Company.

11. Ether. Anhydrous, sp. gr. 0.72. J. T. Baker and Company.

12. Hydrochloric acid. C. P., sp. gr. 1.18 to 1.19. General Chemical Company.

a. A solution (0.1945N) for reference, was standardized by precipitating and weighing its chlorine as silver chloride (68).

b. The other dilute solutions of hydrochloric acid were standardized by titration against a standard solution of sodium hydroxide, using Methyl Red as indicator.

c. The concentrated solutions of hydrochloric acid were prepared by diluting the C. P. acid with distilled water to a specific gravity of 1.112 or 1.126 and were standardized by converting the chlorine into silver chloride which was weighed (68).

13. Hydrogen peroxide. Thirty percent. Merck and Company.

14. Hydroxylamine hydrochloride. C. P. General Chemical Company.

15. Hypochlorous acid. An aqueous solution of 65 grams of sodium carbonate was added to 100 grams of bleaching powder in a liter of warm water. This mixture was then diluted to two liters and filtered. To a measured volume of the filtrate an equivalent amount of boric acid dissolved in water was added just before use. The iodine freed when hypochlorous acid was added from a burette to 25 milliliters of ten percent potassium iodide solution, acidified with hydrochloric acid and diluted to half a liter, was titrated with standard sodium thiosulfate using starch paste as an indicator (228). The concentration of the hypochlorous acid was checked electrometrically by Penot's method (23). A standard solution of sodium arsenite was added to the hypochlorous acid and the electromotive force of a cell with a platinum electrode and

a standard calomel electrode was read after each addition.

Data of standardization

Method		Sodium thiosulfate milliliter 0.1027N	Sodium arsenite milliliter 0.1000N	Hypochlorous acid milliliter	Hypochlorous acid normality
Electrometric	1		15.15	25.00	0.0606
	2		15.20	25.00	0.0608
	Mean				0.0607
Volumetric	1	14.75		25.00	0.0606
	2	14.70		25.00	0.0604
	3	14.70		25.00	0.0604
	Mean				0.0605

16. Iodine. Resublimed. Merck and Company. A solution approximately tenth normal was prepared by dissolving 12.7 grams of iodine in sufficient ten percent potassium iodide to make one liter.

17. Mercury. C. P. J. T. Baker and Company.

18. Methyl Red. Hartman-Leddon Company.

19. Monochloroacetic acid. General Chemical Company.

20. Nitric acid. C. P., sp. gr. 1.42. General Chemical Company.

21. Paraffin. Standard Oil Company.

22. Perchloric acid. General Chemical Company.

23. Potassium chlorate. Standard Colorimeter Company.

24. Potassium dichromate. C. P. General Chemical Company.

25. Potassium hydroxide. C. P. General Chemical Company.

26. Potassium iodide. C. P. General Chemical Company.

27. Potassium nitrate. C. P. General Chemical Company.

28. Potassium sulfide. C. P. J. T. Baker and Company.

29. Silver nitrate. Reagent. Merck and Company.

30. Sodium arsenite. Sodium arsenite, 0.1000N, was prepared by dissolving 4.9555 grams of 99.8 percent arsenious oxide, dried at 110°C., in twenty percent sodium hydroxide, and neutralizing this solution to phenolphthalein with dilute sulfuric acid, adding 500 milliliters of water containing 25 grams sodium bicarbonate, and making up to one liter (205).

31. Sodium bicarbonate. Reagent. General Chemical Company.

32. Sodium carbonate. C. P., anhydrous. General Chemical Company.

34. Sodium hydroxide. C. P. General Chemical Company.

a. The dilute solutions were standardized by titration with standard hydrochloric acid using Methyl Red as indicator.

b. A forty percent solution was made by dissolving forty grams of sodium hydroxide in sixty milliliters of water.

35. Sodium peroxide. Reagent. General Chemical Company.

36. Sodium sulfate. C. P. General Chemical Company.

37. Sodium thiosulfate. C. P. General Chemical Company. An approximately tenth normal solution was prepared by dissolving the required weight of sodium thiosulfate in distilled water and was standardized after standing for fifteen days by

titrating the iodine set free from potassium iodide by a measured volume of standard potassium dichromate solution, using starch paste as an indicator (68).

38. Stannous chloride. C. P. General Chemical Company. One hundred grams of stannous chloride were dissolved in 100 milliliters of nearly boiling concentrated hydrochloric acid and diluted with fifty milliliters of water.

39. Sulfuric acid. C. P., sp. gr. 1.84. General Chemical Company.

40. Wool. Plain-woven wool batiste was boiled one hour in one hundred volumes of water, rinsed, dried at room temperature, cut for analysis, and extracted continuously with anhydrous ether for eighteen hours.

41. Zinc. Mossy. General Chemical Company.

Methods

A. Chlorination of wool

Approximately five grams of wool brought to constant weight at 105-110°C. (186) were immersed in 200 milliliters of 0.06N hypochlorous acid in a stoppered flask at 25±0.1°C., in a water bath for one hour, rinsed in distilled water until the rinse no longer produced an opalescence with silver nitrate, and dried in air. Wool of 0.07 percent ash, 16.29 percent nitrogen, 0.36 percent sulfate sulfur, 4.07 percent total sulfur and a wet warp breaking strength of twelve pounds, upon analysis after chlorination (residual weight 98.4 percent) yielded no ash, 15.98 percent nitrogen, no sulfate sulfur, and 3.72 percent total sulfur, and showed a breaking strength of ten pounds(Tables V, VI, and VII).

Hypochlorous acid, 0.06N, was chosen for the chlorination of wool since this was the highest concentration which did not appreciably affect the wool as shown in Tables I, II, and III (13).

B. Degradation of chlorinated wool by acid

A five-gram sample of chlorinated wool was immersed in 200 milliliters of water, 0.50N, 1.00N, 3.00N, or 6.00N hydrochloric acid at $25 \pm 0.1^{\circ}C$. in a water bath for ten hours and rinsed in distilled water until the rinse gave no test for chloride. Tests at $100^{\circ}C$. for one hour were made with water or 0.25N, 0.50N, or 0.75N hydrochloric acid in balloon flasks fitted with water-cooled reflux condensers and heated in a boiling water bath.

The strips for test of strength were broken wet immediately after rinsing; the residual chlorinated wool was dried in air at room temperature before analysis for nitrogen and dried to constant weight at 105 to $110^{\circ}C$. before determination of sulfur.

C. Degradation of chlorinated wool by alkali

A sample of chlorinated wool was immersed in 200 milliliters of water or 0.05N, 0.10N, 0.15N, or 0.20N sodium hydroxide at $40 \pm 0.1^{\circ}C$., in a water bath for ten hours and rinsed in distilled water until the rinse gave no test for alkali with phenolphthalein. The residual wool was analyzed for wet strength, nitrogen, and sulfur.

D. Ash

A five-gram sample of wool brought to constant weight at 105 to 110°C. in a weighing bottle by the method of tares was transferred to a crucible and ignited to constant weight in a muffle furnace at dull red heat.

E. Breaking strength

Ten specimens were cut 1.5 inches wide and six inches in the direction of the warp, no specimen nearer the selvage than one-tenth the width of the fabric, and no two specimens including the same warp yarns. These specimens were raveled accurately to a width of one inch by taking approximately the same number of warp yarns from either edge.

A Scott Universal Tester with autographic recorder was used to determine the strength of the one-inch strips. The two-inch jaws of the machine were clamped three inches apart in the strip and the machine was run at the rate of twelve inches per minute until the fabric was strained to its breaking point (5, 6).

F. Nitrogen

The air-dried residual wool was digested with fifty milliliters of concentrated sulfuric acid, a drop of mercury, and ten grams of sodium sulfate. After cooling and diluting the solution with 200 milliliters of water, a small piece of paraffin, 160 milliliters of forty percent sodium hydroxide, twenty milliliters of ten percent potassium sulfide, and a small piece of zinc were added and the mixture was distilled at once into a measured volume of standard hydrochloric acid. The excess acid was titrated with standard sodium hydroxide using Methyl Red as indicator(68).

G. Sulfur

1. Sulfate sulfur

Five grams of wool were dissolved in fifty milliliters of thirty percent hydrochloric acid by heating in a boiling water bath. The solution was cooled, diluted with an equal volume of water, and filtered. The filtrate was brought to boiling and its sulfur precipitated as barium sulfate by the addition of 25 milliliters of ten percent barium chloride. After standing fifteen hours the precipitate was filtered, washed free of chloride, and ignited to constant weight (152).

2. Sulfite sulfur

Five grams of wool were placed with sixty milliliters of a solution of stannous chloride and ten milliliters of ten percent barium chloride in a balloon flask fitted with a delivery tube dipping into a flask containing 100 milliliters of ten percent potassium hydroxide and fifty to 100 milliliters of tenth normal iodine. After the contents of the balloon flask were boiled vigorously for thirty minutes, the alkaline iodine solution was boiled for a few minutes, filtered, acidified with hydrochloric acid, concentrated to a small volume, and again filtered. This filtrate was heated to boiling before precipitation of its sulfur as barium sulfate with ten percent barium chloride. The precipitate was filtered, washed free of chloride, and ignited to constant weight. A yield of sulfur in excess of 0.25 percent, that of Cotswold wool, is expressed as sulfite sulfur (13, 76).

3. Total sulfur

a. Benedict-Denis method

Five grams of wool were digested with 100 milliliters of a solution, one part concentrated nitric acid and two parts water. After addition of 100 milliliters of Benedict-Denis reagent the solution was evaporated to dryness, the residue heated to dull redness for ten minutes, dissolved in 100 milliliters of ten percent hydrochloric acid, and filtered. The filtrate was heated to boiling and the sulfur precipitated as barium sulfate by the addition of 25 milliliters of ten percent barium chloride. After twelve to fifteen hours the precipitate was filtered onto the asbestos mat of a weighed Gooch crucible, washed free of chloride, and ignited to constant weight at dull red heat in an electric muffle furnace (21, 50).

b. Parr bomb method

Three-tenths gram of wool, one gram of potassium chlorate, fifteen grams of sodium peroxide, and

0.2 gram of benzoic acid were ignited in a Parr bomb. The fused mixture was dissolved in hot water and made slightly acid with hydrochloric acid. This solution was diluted to 400 milliliters and its sulfur precipitated and weighed as barium sulfate (175).

c. Perchloric acid method

One gram of wool was digested with one gram of potassium nitrate, five milliliters of concentrated nitric acid, 0.16 gram of ammonium vanadate, two to four grams of monochloroacetic acid, and fifteen milliliters of seventy percent perchloric acid, and then heated at 180°C. until completely oxidized. Ten milliliters of concentrated hydrochloric acid were added, the mixture was heated and then 100 milliliters of water and 0.2 gram of hydroxylamine hydrochloride were added. After heating, the mixture was filtered, and the filtrate diluted to 400 milliliters before its sulfur was precipitated and weighed as barium sulfate (208).

The Benedict-Denis (50) method for the determination of total sulfur has been used for proteins (105) although it has been reported as giving low results for proteins containing both methionine and cystine because of incomplete oxidation of the methionine sulfur (173, 192). Wool has been reported to contain from 0.1 (125) to 0.6 (9, 10, 16) percent of methionine. Table IV compares the Benedict-Denis, perchloric acid, and Parr bomb methods. The Benedict-Denis and Parr bomb methods gave results that agreed within experimental error; the perchloric acid method gave far lower results. The Benedict-Denis method was used throughout this study since larger and more representative samples could be analyzed.

Data

TABLE I. EFFECT OF HYPOCHLOROUS ACID IN ONE HOUR AT 25°C. ON THE WEIGHT AND SULFUR OF WOOL

Determination	Hypochlorous acid	Wool	Residue		Barium sulfate	Sulfur	
number	normality	gram	gram	percentage of wool	gram	percentage of wool	percentage of residue
1	0.0000	6.6536	6.6484	99.9	1.7631	3.64	
2		6.5154	6.4858	99.5	1.7088	3.60	
3		6.6279	6.6091	99.7	1.7607	3.65	
4		6.6547	6.6221	99.5	1.7510	3.61	
Mean				99.7		3.63	3.64
Deviation				0.2		0.02	
1	0.0131	6.6444	6.6320	99.8	1.7339	3.58	
2		5.8934	5.8324	99.0	1.5648	3.65	
3		5.8125	5.7713	99.3	1.5303	3.62	
Mean				99.4		3.62	3.64
Deviation				0.3		0.02	
1	0.0528	5.8285	5.6812	97.5	1.5077	3.65	
2		5.5158	5.4314	98.5	1.4222	3.60	
3		5.3723	5.2497	97.7	1.3760	3.60	
Mean				97.9		3.62	3.70
Deviation				0.4		0.02	

TABLE II. EFFECT OF HYPOCHLOROUS ACID IN ONE HOUR AT 25°C. ON THE NITROGEN OF WOOL

Determination number	Hypochlorous acid normality	Wool gram	Hydrochloric acid milliliter 0.4672N	Sodium hydroxide milliliter 0.2243N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0.0000	6.5879	200.00	75.64	16.26	
2		6.7173	200.00	68.56	16.28	
Mean					16.27	16.32
Deviation					0.01	
1	0.0131	6.0073	200.00	105.03	16.30	
2		5.9651	200.00	108.25	16.24	
Mean					16.27	16.37
Deviation					0.03	
1	0.0528	5.5925	200.00	127.88	16.21	
2		5.3041	200.00	141.40	16.30	
Mean					16.26	16.61
Deviation					0.05	

TABLE III. EFFECT OF HYPOCHLOROUS ACID IN ONE HOUR AT 25°C. ON THE STRENGTH OF WOOL

Determination	Normality of hypochlorous acid							
	0.0000	0.0070	0.0131	0.0265	0.0528	0.0806	0.1209	0.1377
	Breaking strength of wet warp							
number	pounds per inch	pounds per inch	pounds per inch	pounds per inch	pounds per inch	pounds per inch	pounds per inch	pounds per inch
1	13	11	11	12	13	13	10	6
2	13	13	11	12	12	13	8	10
3	12	13	13	11	11	11	12	8
4	13	11	12	13	11	12	11	8
5	13	14	14	11	11	12	10	9
6	13	13	12	11	11	8	7	8
7	12	11	12	14	13	9	9	9
8	12	11	12	12	12	11	5	7
9	15	11	12	11	11	6	10	7
10	15	12	10	13			7	7
Mean	13	12	12	12	12	10	9	8
Deviation	1	1	1	1	1	2	2	1

TABLE IV. A COMPARISON OF THE BENEDICT-DENIS, PARR BOMB, AND PERCHLORIC ACID METHODS

Determination number	Method	Wool gram	Barium sulfate gram	Sulfur percentage of wool	Analyst
1	1. Benedict-Denis	4.2515	1.1325	3.66	
2		4.5382	1.2096	3.66	
3		4.1043	1.0841	3.63	
4		4.5528	1.2089	3.65	
5		4.7180	1.2560	3.66	
6		4.5721	1.2220	3.67	
Mean				3.66	Leekley
Deviation				0.01	
1		4.7754	1.2702	3.65	
2		4.2949	1.1455	3.66	
3		4.2530	1.1265	3.64	
4		4.0846	1.0948	3.68	
Mean				3.66	Barr
Deviation				0.01	
1	2. Parr Bomb	0.5084	0.1311	3.54	
2		0.6233	0.1608	3.54	
3		0.5539	0.1441	3.57	
4		0.5326	0.1382	3.56	
5		0.5463	0.1411	3.55	
Mean				3.55	Leekley
Deviation				0.01	
1		0.5800	0.1507	3.57	
2		0.6196	0.1578	3.50	
3		0.5876	0.1491	3.49	
4		0.5566	0.1440	3.55	
5		0.6051	0.1546	3.51	
Mean				3.52	Barr
Deviation				0.03	
1	3. Perchloric acid	0.9801	0.2171	3.04	
2		0.9816	0.2165	3.03	
3		0.9840	0.2230	3.11	
4		0.9833	0.2176	3.04	
5		0.9858	0.2131	2.97	
6		0.9840	0.2107	2.94	
Mean				3.02	Leekley
Deviation				0.05	

TABLE V. THE WEIGHT AND NITROGEN OF WOOL AND CHLORINATED WOOL

Determination number	Fabric	gram	Residue gram	Residue percentage of wool	Hydrochloric acid normality	Hydrochloric acid milliliter	Sodium hydroxide milliliter 0.2160N	Nitrogen percentage of fabric
1	Wool	4.9377			0.3634	175.00	28.22	16.31
2		5.0502				175.00	22.20	16.31
3		4.9710				175.00	27.18	16.26
4		5.2140			0.3390	250.00	111.35	16.31
5		5.2601				250.00	110.12	16.24
Mean								16.29
Deviation								0.03
1	Chlorinated wool	5.0167	4.9372	98.4				
2		5.2691	5.1881	98.5				
3		5.2371	5.1552	98.4				
4		5.1871	5.1048	98.4				
5		5.0828				175.00	26.20	15.97
6		4.8934				175.00	36.60	15.94
7		5.4323			0.1945	400.00	73.25	15.98
8		5.2424				400.00	82.52	16.03
Mean				98.4				15.98
Deviation				0.0				0.03

TABLE VI. THE ASH, SULFATE SULFUR, SULFITE SULFUR, AND TOTAL SULFUR OF WOOL AND CHLORINATED WOOL

Determination number	Fabric		Ash		Barium sulfate	Sulfate sulfur	Sulfite sulfur	Total sulfur
		gram	gram	percentage of fabric	gram	percentage of fabric	percentage of fabric	percentage of fabric
1	Wool	5.1725	0.0039	0.07				
2		5.0960	0.0038	0.07				
3		4.9900			1.5008			4.13
4		5.2180			1.5294			4.03
5		5.2069			1.5721			4.15
6		5.1824			1.4890			3.95
7		5.2170			0.1330	0.35		
8		5.2002			0.1375	0.36		
Mean				0.07		0.36	0	4.07
Deviation				0.00		0.01		0.08
1	Chlorinated wool	5.2379			1.4290			3.75
2		5.2289			1.4126			3.71
3		5.2387			1.4102			3.70
4		5.1920			1.4108			3.73
Mean				0		0	0	3.72
Deviation								0.02

TABLE VII. THE STRENGTH OF WOOL AND CHLORINATED WOOL

Determination	Breaking strength of wet warp	
	Wool	Chlorinated wool
number	pounds per inch	pounds per inch
1	12	9
2	12	11
3	12	11
4	14	10
5	12	9
6	12	9
7	10	11
8	11	10
9	11	9
10	12	9
Mean	12	10
Deviation	1	1

TABLE VIII. EFFECT OF ACID IN TEN HOURS AT 25°C. ON THE WEIGHT AND SULFUR OF CHLORINATED WOOL

Determination number	Hydrochloric acid normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfur percentage of wool	Sulfur percentage of residue
1	0	4.9744	4.8217	96.9			
2		4.9897	4.8491	97.2			
3		5.0844	4.9387	97.1			
4		4.9974	4.8526	97.1			
5		4.9814	4.8400	97.2	1.3239	3.65	
6		5.1670			1.3971	3.71	
7		5.1435			1.3889	3.71	
8		5.0640			1.3475	3.65	
Mean				97.1		3.68	3.79
Deviation				0.1		0.03	
1	0.50	5.0821	4.9207	96.8	1.2830	3.47	
2		5.0780	4.9350	97.2	1.3071	3.54	
3		4.9522	4.8040	97.0	1.2566	3.49	
4		5.0809	4.9300	97.0			
5		5.0827	4.9386	97.2	1.3061	3.53	
Mean				97.1		3.53	3.64
Deviation				0.0		0.03	
1	1.00	5.0654	4.9250	97.2			
2		4.9804	4.8285	97.0	1.2068	3.33	
3		5.1016	4.9554	97.1	1.3234	3.56	
4		5.0244	4.8568	96.7	1.3278	3.63	
5		5.0250	4.8590	96.7			
Mean				96.9		3.51	3.62
Deviation				0.2		0.12	

TABLE VIII. (Continued)

Determination number	Hydrochloric acid normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfur percentage of wool	Sulfur percentage of residue
1	3.00	5.2235	5.0060	95.8	1.3307	3.50	
2		5.0132	4.8000	95.7	1.2616	3.46	
3		4.9992	4.7920	95.9	1.2724	3.50	
4		4.9469	4.7354	95.7			
Mean				95.8		3.49	3.64
Deviation				0.1		0.02	
1	6.00	5.2243	4.8233	92.3	1.2949	3.40	
2		4.8332	4.4034	91.1			
3		5.0079	4.6027	91.9			
4		4.9476	4.5071	91.1	1.2394	3.44	
Mean				91.6		3.42	3.73
Deviation				0.5		0.02	

TABLE IX. EFFECT OF ACID IN TEN HOURS AT 25°C. ON THE NITROGEN OF CHLORINATED WOOL

Determination number	Hydrochloric acid normality	Wool gram	Hydrochloric acid milliliter 0.3634N	Sodium hydroxide milliliter 0.2160N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0	4.9252	175.00	35.88	15.88	
2		4.8714	200.00	82.15	15.80	
3		5.0188	175.00	31.80	15.83	
Mean					15.84	16.31
Deviation					0.03	
1	0.50	5.1104	205.00	78.80	15.75	
2		5.1196	175.00	27.95	15.75	
3		4.9896	175.00	34.92	15.73	
4		5.1146	200.00	69.85	15.77	
Mean					15.75	16.22
Deviation					0.01	
1	1.00	5.1901	200.00	66.80	15.72	
2		5.1050	200.00	69.20	15.84	
3		5.1271	200.00	67.98	15.85	
Mean					15.80	16.31
Deviation					0.06	
1	3.00	5.2200	175.00	28.00	15.44	
2		4.9173	154.20	8.92	15.41	
3		5.2115	175.00	26.30	15.57	
4		5.1636	175.00	29.12	15.55	
Mean					15.49	16.17
Deviation					0.07	

TABLE IX. (Continued)

Determination number	Hydrochloric acid normality	Wool gram	Hydrochloric acid milliliter 0.3634N	Sodium hydroxide milliliter 0.2160N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	6.00	5.0121	150.00	7.42	14.79	
2		4.9053	150.00	13.50	14.73	
3		4.9325	150.00	11.12	14.80	
4		4.9647	150.00	8.42	14.87	
5		5.0197	150.00	7.80	14.74	
Mean					14.79	16.15
Deviation					0.04	

TABLE X. EFFECT OF ACID IN TEN HOURS AT 25°C. ON THE STRENGTH OF CHLORINATED WOOL

Determination:	Normality of hydrochloric acid				
	0.00	0.50	1.00	3.00	6.00
	Breaking strength of wet warp				
number	pounds per inch	pounds per inch	pounds per inch	pounds per inch	pounds per inch
1	8	9	8	9	4
2	11	10	9	6	3
3	7	8	9	7	5
4	9	11	9	9	6
5	11	11	9	10	5
6	9	11	10	9	3
7	10	11	10	6	4
8	10	10	9	7	3
9	9	7	7	5	5
10	11	8	9	5	7
Mean	10	10	9	7	5
Deviation	1	1	1	1	1

TABLE XI. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE WEIGHT AND SULFUR OF CHLORINATED WOOL

Determination number	Hydrochloric acid normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfur percentage of wool	Sulfur percentage of residue
1	0	4.4448	4.1983	94.4			
2		4.5450	4.3006	94.6			
3		4.5672	4.3040	94.2			
4		5.2274	4.9471	94.6			
5		5.2516	4.9869	95.0			
6		5.0377			1.3271	3.62	
7		5.1206			1.4084	3.78	
8		5.0883			1.3512	3.65	
Mean				94.6		3.68	3.89
Deviation				0.2		0.06	
1	0.25	5.2687	4.7768	90.5	1.2730	3.32	
2		5.3827	4.8354	89.8	1.2956	3.31	
3		5.4097	4.8565	89.8	1.3255	3.37	
4		5.2965	4.7526	89.7			
5		5.3905	4.8491	90.0			
Mean				90.0		3.33	3.70
Deviation				0.2		0.02	

TABLE XI. (Continued)

Determination number	Hydrochloric acid normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfur percentage of wool	Sulfur percentage of residue
1	0.50	5.1690	4.3663	84.5	1.2009	3.19	
2		5.2454	4.3919	83.7	1.1884	3.11	
3		5.3835	4.5581	84.7	1.2250	3.13	
4		5.2325	4.4604	85.2	1.2065	3.17	
5		5.1372	4.3311	84.3	1.1815	3.16	
Mean				84.5		3.15	3.73
Deviation				0.4		0.03	
1	0.75	4.9934	3.8961	78.0	1.1070	3.03	
2		5.2415	4.1634	79.4	1.1730	3.07	
3		5.2291	4.0793	78.0	1.1773	3.09	
Mean				78.5		3.06	3.90
Deviation				0.6		0.02	

TABLE XII. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE NITROGEN OF CHLORINATED WOOL

Determination number	Hydrochloric acid normality	Wool gram	Hydrochloric acid milliliter 0.3390N	Sodium hydroxide milliliter 0.2160N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0	5.2305	200.00	41.75	15.74	
2		5.1701	200.00	45.80	15.69	
3		5.1199	202.10	50.82	15.74	
Mean					15.72	16.62
Deviation					0.02	
1	0.25	5.1707	200.00	64.92	14.57	
2		5.0619	200.00	66.52	14.79	
3		5.2252	200.30	61.28	14.65	
Mean					14.67	16.30
Deviation					0.08	
1	0.50	5.1972	200.00	83.05	13.44	
2		5.2054	200.00	83.10	13.41	
3		5.1160	200.00	87.32	13.40	
Mean					13.42	15.88
Deviation					0.02	
1	0.75	5.3410	200.00	98.52	12.20	
2		5.2658	200.00	99.95	12.29	
3		5.2249	200.00	99.40	12.42	
Mean					12.30	15.67
Deviation					0.08	

TABLE XIII. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE STRENGTH OF CHLORINATED WOOL

Determination:	Normality of hydrochloric acid			
	0.00	0.25	0.50	0.75
	Breaking strength of wet warp			
number	pounds per inch	pounds per inch	pounds per inch	pounds per inch
1	9	5	1	
2	11	3	1	
3	11	5	0	
4	11	6	1	
5	10	4	1	
6	10	6	0	
7	9	6	1	
8	9	6	1	
9	11	5	1	
10		4	1	
Mean	10	5	1	<1
Deviation	1	1	0	

TABLE XIV. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE WEIGHT AND SULFUR OF CHLORINATED WOOL

Determination number	Sodium hydroxide normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfur percentage of wool	Sulfur percentage of residue
1	0	5.4301	5.2366	96.4	1.4584	3.69	
2		5.2513	5.0485	96.1	1.4030	3.67	
3		5.3300	5.1451	96.5	1.4467	3.73	
4		5.2513	5.0613	96.4	1.4258	3.73	
5		5.2096			1.3797	3.64	
6		5.1637			1.3590	3.61	
Mean				96.4		3.68	3.82
Deviation				0.1		0.04	
1	0.05	5.1082	4.5503	89.1	1.0845	2.92	
2		4.8987	4.3756	89.3	1.0273	2.88	
3		5.0764	4.5490	89.6	1.0461	2.83	
Mean				89.3		2.88	3.23
Deviation				0.2		0.03	
1	0.10	5.2193			0.8358	2.20	
2		5.3053	4.4963	84.8	0.8563	2.22	
3		5.2225	4.4499	85.2	0.8669	2.28	
4		5.1634	4.3922	85.1	0.8646	2.30	
5		5.1911	4.4047	84.9	0.8648	2.29	
Mean				85.0		2.26	2.66
Deviation				0.2		0.04	

TABLE XIV. (Continued)

Determination number	Sodium hydroxide normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfur percentage of wool	Sulfur percentage of residue
1	0.15	5.2648	3.9489	75.0	0.7210	1.88	
2		5.2902	3.9603	74.9	0.7086	1.84	
3		5.2138	3.9772	76.3	0.7136	1.88	
4		5.2066	3.9424	75.7	0.7132	1.88	
Mean				75.5		1.87	2.48
Deviation				0.5		0.02	
1	0.20	5.2584	3.4576	65.7	0.6201	1.62	
2		5.2173	3.4588	66.3	0.6264	1.65	
3		5.3115	3.5212	66.3	0.6516	1.68	
4		4.9593	3.2483	65.5	0.6032	1.67	
Mean				66.0		1.66	2.52
Deviation				0.4		0.02	

TABLE XV. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE NITROGEN OF CHLORINATED WOOL

Determination number	Sodium hydroxide normality	Wool gram	Hydrochloric acid milliliter 0.3150N	Sodium hydroxide milliliter 0.2160N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0.00	5.3182	200.00	15.75	15.70	
2		5.2180	200.00	19.95	15.76	
3		5.3540	200.00	14.15	15.68	
4		5.2901	200.00	17.30	15.69	
Mean					15.71	16.30
Deviation					0.03	
1	0.05	5.1311	200.00	41.00	14.78	
2		5.2290	200.00	35.80	14.81	
3		5.4770	200.00	25.30	14.72	
4		5.3558	200.00	30.00	14.78	
Mean					14.77	16.54
Deviation					0.03	
1	0.10	4.9918	200.00	65.18	13.73	
2		5.0002	210.00	78.62	13.77	
3		4.9593	200.00	65.88	13.78	
Mean					13.76	16.19
Deviation					0.02	

TABLE XV. (Continued)

Determination number	Sodium hydroxide normality	Wool gram	Hydrochloric acid milliliter 0.3150N	Sodium hydroxide milliliter 0.2160N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0.15	5.3480	200.00	68.75	12.61	
2		5.2602	200.00	72.25	12.62	
3		5.2418	200.00	71.35	12.65	
4		5.2680	200.00	73.40	12.54	
Mean					12.61	16.70
Deviation					0.03	
1	0.20	5.2230	200.00	106.00	10.76	
2		5.2092	200.00	104.70	10.86	
3		5.1480	200.00	107.00	10.85	
Mean					10.82	16.39
Deviation					0.04	

TABLE XVI. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE STRENGTH OF CHLORINATED WOOL

Determination	Normality of sodium hydroxide	
	0.00	0.05
	Breaking strength of wet warp	
number	pounds per inch	pounds per inch
1	8	
2	7	
3	9	
4	11	
5	11	
6	9	
7	10	
8	10	
9	9	
10	11	
Mean	10	<1
Deviation	1	

DISCUSSION OF RESULTS

This quantitative study of the acid and alkaline degradation of wool chlorinated one hour at 25°C. by 0.06N hypochlorous acid was made in 1934 (12) before the development of the sulfuryl chloride process.

The degradation of chlorinated wool in forty-volume baths by hydrochloric acid, 0.00, 0.05, 1.00, 3.00, and 6.00 N, in ten hours at 25°C. (Tables VIII, IX, and X), by hydrochloric acid, 0.00, 0.25, 0.50, and 0.75 N, in one hour at 100°C. (Tables XI, XII, and XIII), and by sodium hydroxide, 0.00, 0.05, 0.10, 0.15, and 0.20 N, in ten hours at 40°C. (Tables XIV, XV, and XVI) is summarized in Table XVII.

Changes in the weight, composition, and mechanical failure of the chlorinated wool and a similar untreated wool (14, 15) brought about by acid at 25°C. and at 100°C. are compared in Graphs 1 and 2; Graph 3 contrasts the effects of alkali at 40°C. on chlorinated wool and wool (12).

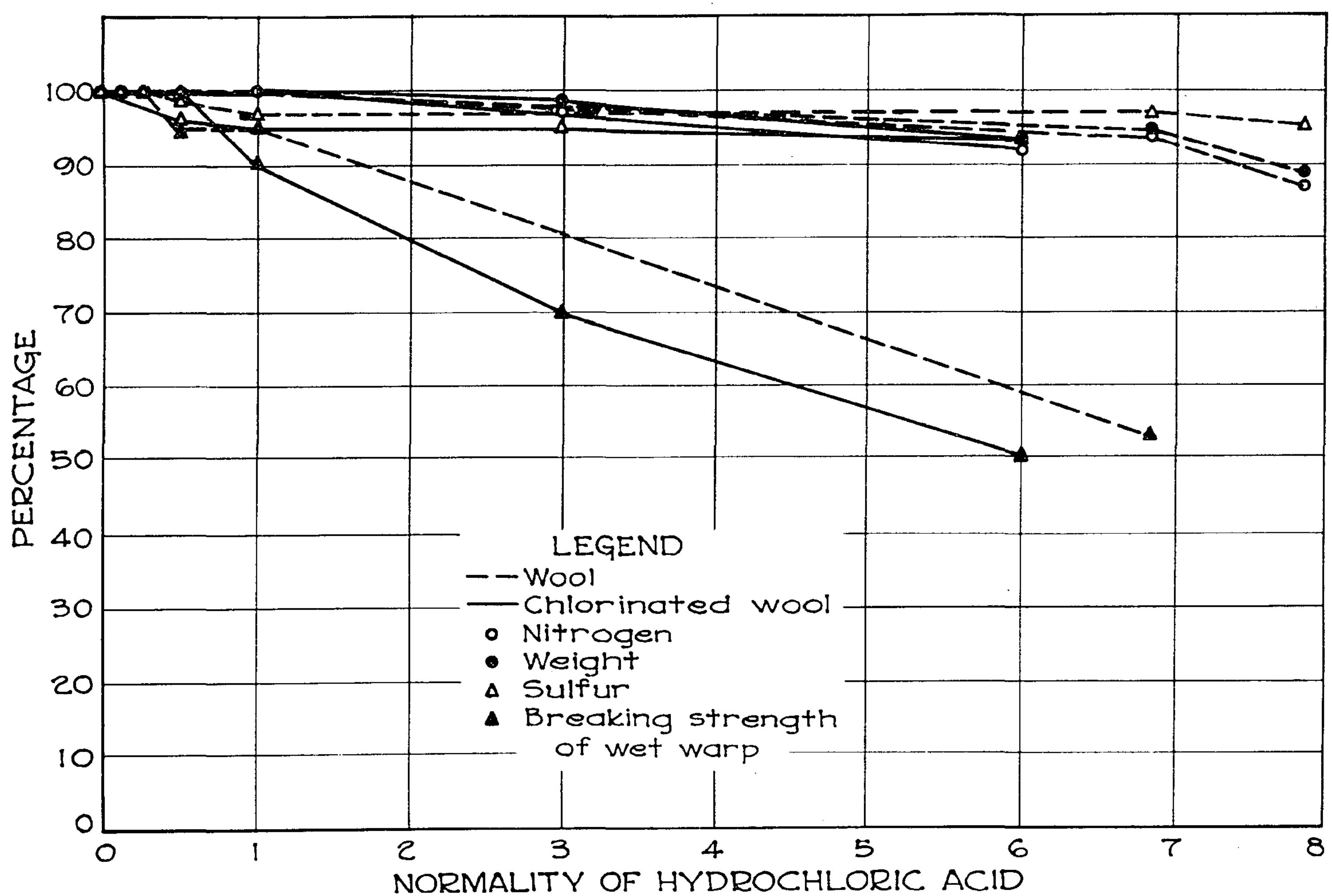
Although the chlorinated wool suffered but the same loss in weight as wool by acid at 25°C. its wet strength nearly paralleled that of wool at a ten percent lower level and was completely destroyed at 6.86N, a concentration at which wool retained 47 percent of its strength.

The wools were much more degraded by acid at 100°C. than at 25°C., the chlorinated wool more than the wool although in neither treatment with acid was the ratio of sulfur to nitrogen decreased.

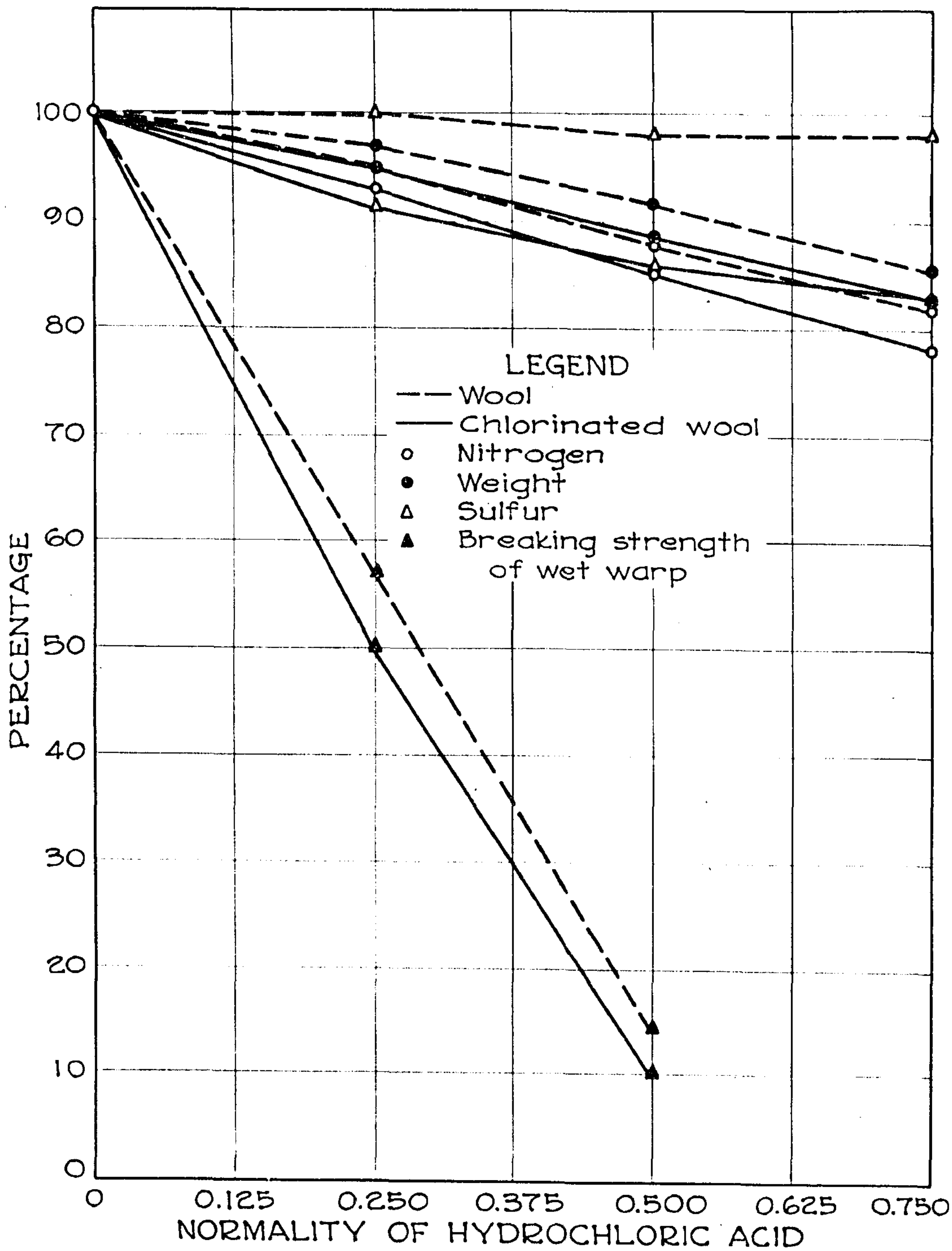
Alkali caused a much greater loss of weight in chlorinated wool than in wool and the wet strength of the former was completely destroyed in one hour at 40°C. by 0.05<u>N</u> sodium hydroxide although the latter retained five percent of its strength after ten hours at this temperature in alkali four times as concentrated. After treatment in 0.00, 0.05, 0.10, 0.15, and 0.20 <u>N</u> sodium hydroxide the chlorinated wool's ratios of sulfur to nitrogen were, respectively, 0.23, 0.19, 0.16, 0.15, and 0.15, as compared with these corresponding values for wool, 0.25, 0.20, 0.18, 0.15, and 0.14.

TABLE XVII. EFFECT OF ACID AND ALKALI ON THE WEIGHT, NITROGEN, SULFUR, AND WET STRENGTH OF CHLORINATED WOOL

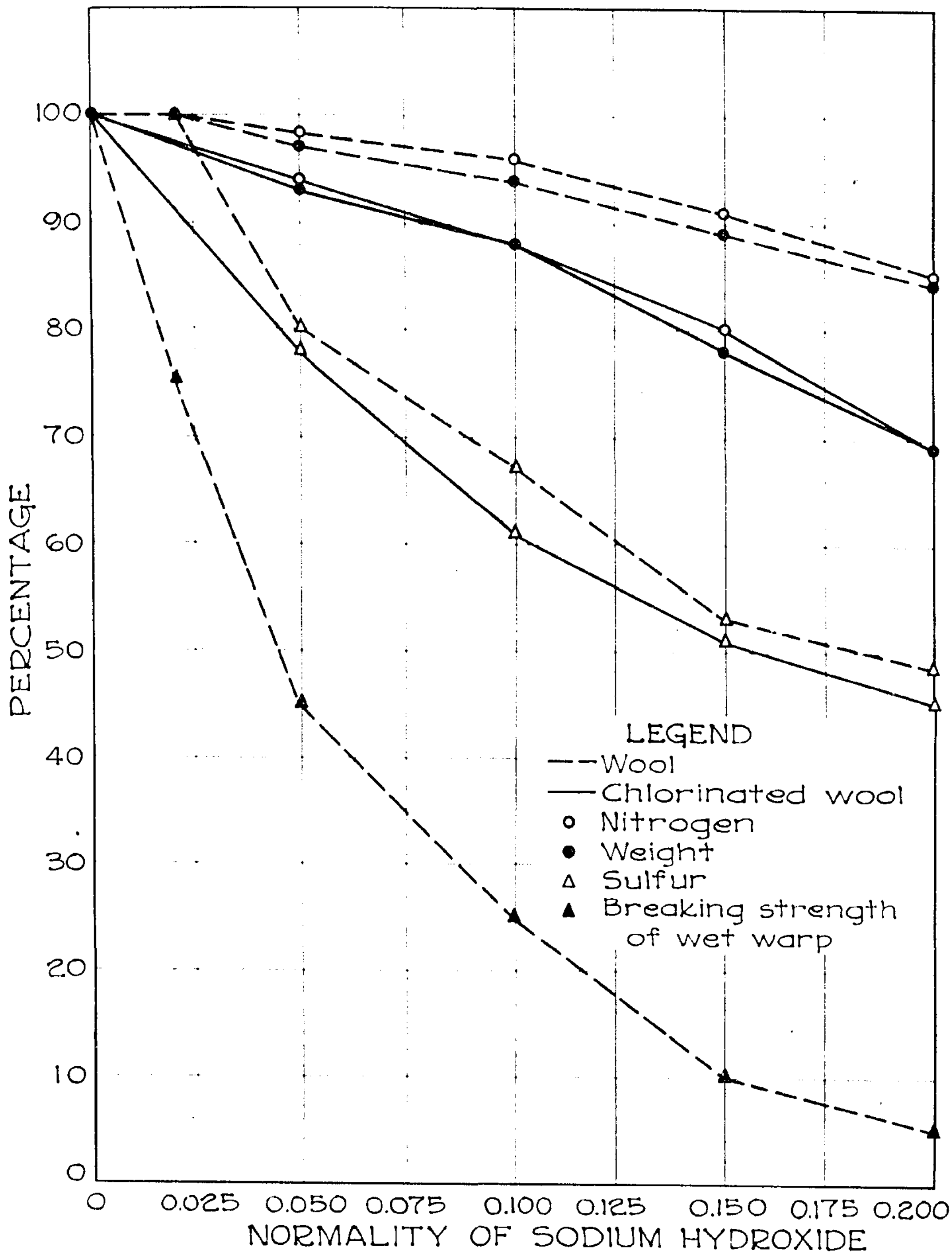
Hydrolytic agent		Time	Temperature	Weight	Nitrogen	Sulfur	Ratio of sulfur to nitrogen	Breaking strength of wet warp
	normality	hour	°C.	percentage of wool	percentage of wool	percentage of wool		pounds per inch
Hydrochloric acid	0.0000	10	25	97.1	15.84	3.68	0.23	10
	0.5000			97.1	15.75	3.53	0.22	10
	1.0000			96.9	15.80	3.51	0.22	9
	3.0000			95.8	15.49	3.49	0.23	7
	6.0000			91.6	14.79	3.42	0.23	5
	0.0000	1	100	94.6	15.72	3.68	0.23	10
	0.2500			90.0	14.67	3.33	0.22	5
	0.5000			84.5	13.42	3.15	0.23	1
	0.7500			78.5	12.30	3.06	0.25	< 1
Sodium hydroxide	0.0000	10	40	96.4	15.71	3.68	0.23	10
	0.0500			89.3	14.79	2.88	0.19	< 1
	0.1000			85.0	13.76	2.26	0.16	
	0.1500			75.5	12.61	1.87	0.15	
	0.2000			66.0	10.82	1.66	0.15	



GRAPH 1. EFFECT OF ACID IN TEN HOURS AT 25°C. ON THE WEIGHT, NITROGEN, SULFUR, AND WET STRENGTH OF WOOL AND CHLORINATED WOOL



GRAPH 2. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE WEIGHT, NITROGEN, SULFUR, AND WET STRENGTH OF WOOL AND CHLORINATED WOOL



GRAPH 5. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE WEIGHT, NITROGEN, SULFUR, AND WET STRENGTH OF WOOL AND CHLORINATED WOOL

SUMMARY

1. Degradation of plain-woven wool, chlorinated by 0.0600$\underline{N}$ hypochlorous acid in one hour at 25°C., by 0.5000 to 6.0000$\underline{N}$ hydrochloric acid in ten hours at 25°C., 0.25 to 0.75$\underline{N}$ hydrochloric acid in one hour at 100°C., and 0.0500 to 0.2000$\underline{N}$ sodium hydroxide in ten hours at 40°C., has been measured by the weight, nitrogen, sulfur, and wet warp breaking strength of the residual wool.

2. Degradation of chlorinated wool by acid in ten hours at 25°C. exceeded that of wool as measured by sulfur or wet strength. The loss in weight and nitrogen was the same for wool and chlorinated wool at 25°C.

3. Both wool and chlorinated wool were much more degraded by acid at 100°C. than at 25°C., the chlorinated wool more than the wool, although chlorinated wool's ratio of sulfur to nitrogen was not decreased at either temperature.

4. Sodium hydroxide in ten hours at 40°C. dissolved the same amount of sulfur from chlorinated wool as from wool but decreased the nitrogen and weight of the chlorinated wool more.

5. The wet strength of chlorinated wool was completely destroyed in one hour at 40°C. by 0.0500$\underline{N}$ sodium hydroxide although wool retained five percent of its

strength after ten hours at 40°C. in 0.2000<u>N</u> sodium hydroxide.

6. The ratio of sulfur to nitrogen of chlorinated wool was decreased with increasing concentration of alkali.

II. FORMALDEHYDE AS A FINISH FOR WOOL

REVIEW OF THE LITERATURE

The action of formaldehyde on gelatin (Abegg 1; Brotman 33; Gerngross 76, 77; Levites 146, Lumiere 155; Moeller 182, 184; Reiner 200, 201; Swyngedauw 237) and the collagen of hide (Bocciardo 28; Casaburi 36; Chater 39; Dohogne 47; Gerngross 71, 72, 73, 74, 78, 79, 80, 82, 83, 87; Griliches 89, 90, 91; Gustavson 93; Hennig 98, 99; Hey 108; Highberger 109, 110; Holland 112; Houben 114; Meunier 164, 165, 166, 173; Moeller 178, 179, 180, 183, 185, 186; Powarnin 194; Schröder 214; Simoncini 221; Stiasny 230; Theis 238, 239; Thomas 241; Thuau 243; Tsai 252, 253; Turley 254) has been studied more than its action on wool or other proteins (Anderson 6; Bach 7; Benedicenti 14; Blum 27; Cooper 45; Davenport 46; Fischer 63; Freeman 67, 111; Lepierre 144; Gortner 86; Loiseleur 152; Mascré 160; Mariyama 187; Pappenheimer 192; Reiner 202; Schwarz 218; Trillat 247).

1898 Although Prud'homme states that formaldehyde shows no action on wool (195) its use as a protective agent for that fiber is foreshadowed in the Pullman patents for tanning hide with formaldehyde (193, 198).

1903 Kann proposes a preparatory treatment with formaldehyde for wool (121, 122, 124, 125):

> "If sheeps' wool or other ceratinic fibres, that is to say, any kind of animal hair, be treated with a solution of formic aldehyde of the formula CH_2O for some time in the cold (or better in the hot) or by the vapours of formaldehyde, and afterwards dried without preliminary washing it will be found that by this treatment the fibre has become much less liable to be affected in the hot by the action of strong bases as, for instance, caustic alkalis, alkali carbonates, alkali sulfides, alkaline earths, etc, as well as by the action of steam and of boiling in water of neutral reaction, without diminishing on the whole the useful properties of the wool. The fibre so treated will resist better the action of the said chemicals and will not be shortened or shrunk"(122).

1913 Earlier practice is reflected in a patent for the use of formaldehyde as a disinfectant for wool (203).

1914 Kann reports that wool treated with four percent formaldehyde lacks affinity for dye while wool treated with but 0.1 to 0.25 percent of commercial formalin possesses affinity for dye and is still protected against alkali (123). Gebhard considers that the decrease in wool's affinity for acid dye and increase in its affinity for basic dye may be explained by the formation of N-methylene wool (69).

1917 Protection of wool by formaldehyde during fulling is patented (37).

1920 Becke patents the use of aldehydes for protecting wool during carbonization (12).

1921 The use of aldehydes or ketones is proposed as pretreatment for animal fibers which are to be treated with alkali (5, 190).

1927 Bell suggests treating dyed wool with formaldehyde and chrome or copper mordents or with three percent formaldehyde and one percent acetic acid at 70°C. for thirty minutes. He observes that the weight of formaldehyde taken up by wool in thirty minutes increases with the volume as well as with the concentration of the aldehydic solution until a maximum of three percent is attained. Bell notices that formaldehyde-treated wool loses formaldehyde at 100°C. (13). Trotman and Trotman describe the resistance to alkali of wool treated for one hour at 75°C. with one percent formaldehyde as superior to that of paraformaldehyde-treated wool (250).

1928 Trotman, Trotman, and Brown treat wool with 0.6 percent formaldehyde in a stoppered bottle for three hours at 75°C. and determine the combined formaldehyde by washing the wool with hydrogen peroxide and distilling the extract with sulfuric acid. They find that this formaldehyde-treated wool contains 0.70 percent formaldehyde and the same total nitrogen as the original wool and that it is stable at 100°C., is diazotizable only after decomposition, and that it shows less affinity than wool for water or neutral-dyeing acid dye but greater resistance to degradation by dilute acid or alkali (one percent of its nitrogen and seven percent of its weight are lost in twenty to thirty minutes' boiling in one percent sulfuric acid; none of its nitrogen is dissolved by tenth normal sodium hydroxide in four hours at 75°C.) (248, 249, 251).

1929 A patent is published for protecting animal fibers by aldehyde during carrotting (29).

1930 Speakman reports that the hygroscopicity of wool is slightly reduced by treatment with formaldehyde (229).

1932 Mann describes formaldehyde as making wool unshrinkable (106, 159).

1934 Another patent proposes formaldehyde for protection of animal hairs (147).

1937 Formaldehyde is recommended for pretreating wool to be waterproofed (163) and for making wool more resistant to tearing and bacterial and chemical attack (30).

1938 By X-ray methods Clark and co-workers observe two interplanar spacings corresponding to values of 2.6 and 3.9 Å. U. in formaldehyde-treated keratins and account for these interferences by polymerized formaldehyde retained in the keratin (41, 42). Katz and Gerngross from similar data in 1926 had classified the tanning of hide with formaldehyde as an adsorption and had noted that only aldehydes which undergo aldolization exert a tanning action (126).

1939 Bowes and Pleass find that the rate of formaldehyde's fixation by goat hair increases with pH and is initially rapid above a pH of 8 although its total fixation is constant, approximately one percent by weight. They suggest that the relatively high combining power of goat hair for formaldehyde, in spite of this hair's low content of lysine, shows that formaldehyde combines with the sulfhydryl group (31, 32).

Sörensen (101, 102, 224, 225, 226, 227, 228) based the use of formaldehyde in his alkalimetric estimation of amino acids on Schiff's preparation (210, 211, 212, 213) of _N_-methylene-amino acids,

$$H_2C=O + H_2NCHRCOOH \longleftrightarrow H_2C=NCHRCOOH + H_2O$$

which was patterned after Kolotow's (134) and Henry's (103) treatment of amines with formaldehyde. Schiff recognized the reaction between formaldehyde and amino hydrogen as incomplete and since his time this equilibrium has come to be considered much more complicated because of the description of additive products, other _N_-methylene products, and _N_-methylol, _N_-polymethylol, and deaminated derivatives (Bergmann 15, 16, 17, 19, 20, 21; Cherbuliez 40; Clarke 43; Clementi 44; Einhorn 53, 54; Franzen 66; Galeotti 68, Gerngross 75; Gortner 85, 271; Homer 113; Komm 135, 136, Kassel 137; Krause 138, 139, 140, 141, 142; Kuzin 143; Löb 151; Nierenstein 189; Sasaki 209; Svehla 236; Tomiyama 244, 245) and because of studies of the titration of amino acids in the presence of formaldehyde (Balson 8; Calvery 35; Dulière 48; Dunn 49, 50, 51; Ebert 52; Harris 25, 26, 94, 95, 96, 97; Henriques 100; Jodidi 117, 118; Kekwick 127; Levy 148, 149; Luers 153; Malfatti 156, 157, 158; Richardson 205, 206; Riehm 207; Solarino 223; Steuart 230; Van Slyke 255).

Other carbonylic compounds such as methylglyoxal (Kisch 132), aromatic aldehydes (Bergmann 18, 22, 23; Erlenmeyer 55, 56, 57, 58, 59, 60, 61; Gerngross 70, 81, 84; Gulland 92; Rohde 208), acetone (Bruckhoff 34; Catelani 38), α-keto-carboxylic acids (Herbst 104, 105), isatin (Franke 65), quinones (Baudisch 11; Binet 24; Fahrion 62; Grasser 88; vom Hove 115; Justin-Mueller 120; King 128; Kisch 129, 130, 131, 133; Liebermann 150; Lumière 154; Mercier 162, Meunier 167, 168, 169, 170, 171, 172, 174, 175, 176, 177; Moeller 181; Schwarin 217; Thomas 240, 242; Weinschenk 188, 191, 204, 232, 233, 256, 257, 258; Zincke 261; 4, 116, 246) and sugars (Akabori 2; Frank 64; Maurer 161; Przylecki 196, 197; Smolenski 222; 3) have been described and used for masking the amino groups of acids or proteins.

In 1932 Levi (145) prepared a mercaptal by the addition of a mercaptan to formaldehyde,

$$H_2C{=}O + HSCH_2CH_3 \longrightarrow H_2C\begin{matrix}OH\\ SCH_2CH_3\end{matrix}$$

Ratner and Clarke's preparation of thiazolidine-4-carboxylic acid (199) by the action of formaldehyde on cysteine,

$$\begin{array}{l} CH_2SH \\ CHNH_2 \\ COOH \end{array} + O{=}CH_2 \longrightarrow \begin{array}{l} CH_2S \\ CHNH \end{array}\!\!>CH_2 \atop COOH \quad + H_2O$$

was preceded by Jowett and Quastel's observation of acetaldehyde's reaction with glutathione (119), Shinohara's observation of the destruction of cysteine's reducing action by formaldehyde (220), and Schubert's observations of methyl glyoxal's and phenyl glyoxal's combination with thiol acids and cysteine's condensation with aldehydes to form readily crystallizable products (215, 216). It has since been found in studying the effect of aldehydes (107, 234), acetone (259), and pyruvic acid (235) on the quantitative determination of cysteine that values obtained for cysteine with the Sullivan, Okuda, or Folin-Marenzi methods become progressively lower as thiazolidine complexes are formed.

The action of formaldehyde on keratin has been regarded as an adsorption, the formation of a molecular combination, a chemical reaction involving nitrogenous groups, sulfhydryl groups, or amino and sulfhydryl groups, and as both a chemical and physical phenomenon.

EXPERIMENTAL PROCEDURE

Materials*

1. Formaldehyde. Thirty-seven percent. Merck and Company. Twenty-five milliliters of 0.2370N sodium hydroxide and ten milliliters of thirty percent hydrogen peroxide were added to 25 milliliters of a one percent formaldehyde solution, this mixture was heated for five minutes and then cooled before titration of the excess sodium hydroxide with standard hydrochloric acid using Litmus as indicator (I, 205).

2. Hydrogen peroxide. Thirty percent. Merck and Company.

3. Wool. Plain-woven wool batiste was prepared in the same way as that described for chlorination.

Methods**

A. Treatment of wool with formaldehyde

Approximately five grams of wool, brought to constant weight at 105 to 110°C., were immersed in 250 milliliters of one percent formaldehyde in a stoppered flask at 70±0.1°C. for one hour and dried in the air at room temperature without rinsing (Tables XVIII, XIX, and XX).

* Materials not listed here have been described before.

** The other methods have been described in Part I.

B. Degradation of formaldehyde-treated wool by acid

A sample of formaldehyde-treated wool was immersed in 250 milliliters of water or 6.00N hydrochloric acid in a stoppered flask at $25^{\circ}\pm0.1^{\circ}$C. in a water bath for ten hours and rinsed in distilled water until the rinse gave no test for chloride. Tests at 100°C. for one hour were made with water or 0.25N, 0.50N, or 0.75N hydrochloric acid in balloon flasks fitted with water-cooled reflux condensers and heated in a boiling water bath.

The strips for test of strength were broken wet immediately after rinsing, the weighed samples were dried in air at room temperature before analysis for nitrogen and dried to constant weight at 105 to 110°C. before determination of sulfur.

C. Degradation of formaldehyde-treated wool by alkali

A sample of formaldehyde-treated wool was immersed in 250 milliliters of water or 0.05N, 0.10N, 0.15N, 0.20N, 0.30N, or 0.40N sodium hydroxide at $40\pm0.1^{\circ}$C. in a water bath for ten hours and rinsed in distilled water until the rinse gave no test for alkali with phenolphthalein. The residual wool was analyzed for wet breaking strength, nitrogen, sulfate sulfur, and total sulfur.

The formaldehyde-treated wool was also rinsed in water, centrifuged, stirred five minutes in 250 milliliters of 38 percent sodium hydroxide at $15 \pm 0.1^{\circ}C.$, rinsed with water until free from alkali, and analyzed for breaking strength, nitrogen, sulfate sulfur and total sulfur.

Data

TABLE XVIII. THE WEIGHT AND NITROGEN OF WOOL AND FORMALDEHYDE-TREATED WOOL

Determination number	Fabric		Residue		Hydrochloric acid	Sodium hydroxide	Nitrogen
		gram	gram	percentage of wool	milliliter 0.3315N	milliliter 0.2387N	percentage of wool
1	Wool	4.5720			200.00	53.80	16.38
2		4.6594			200.00	49.70	16.37
3		4.6977			200.00	47.40	16.40
Mean							16.38
Deviation							0.01
1	Formaldehyde-treated wool	4.6184			200.00	52.40	16.32
2		4.4980			200.00	57.75	16.36
3		5.5690	5.6062	100.7			
4		4.6640	4.6897	100.6			
5		4.5304	4.5554	100.6			
6		5.7600	5.7958	100.6			
Mean				100.6			16.34
Deviation				0.0			0.02

TABLE XIX. THE ASH, SULFATE SULFUR, SULFITE SULFUR, AND TOTAL SULFUR OF WOOL AND FORMALDEHYDE-TREATED WOOL

Determination number	Fabric		Ash		Barium sulfate	Sulfate sulfur	Sulfite sulfur	Total sulfur
		gram	gram	percentage of wool	gram	percentage of wool	percentage of wool	percentage of wool
1	Wool	5.9653	0.0031	0.05				
2		6.2458	0.0024	0.04				
3		4.5172			1.5206			4.62
4		4.4348			1.4806			4.59
5		4.4528			1.5017			4.63
6		4.6352			1.5549			4.61
7		4.4914			1.5203			4.65
8		4.3300			0.2609	0.83		
9		4.3868			0.2654	0.83		
10		4.5370			0.2870	0.87		
Mean				0.05		0.84	0.00	4.62
Deviation				0.01		0.02		0.02
1	Formaldehyde-treated wool	4.3305			1.4596			4.63
2		4.4420			1.4879			4.60
3		4.6556			1.5544			4.59
4		4.3194			0.2479	0.79		
5		4.4853			0.2639	0.81		
6		4.4670			0.2456	0.75		
Mean				0.00		0.78		4.61
Deviation						0.02		0.02

TABLE XX. THE STRENGTH OF WOOL AND FORMALDEHYDE-- TREATED WOOL

Determination: number	Fabric	:Breaking strength of warp: Conditioned pounds per inch	Wet pounds per inch
1	Wool	17	6
2		17	8
3		17	8
4		15	8
5		17	8
6		18	8
7		17	7
8		17	7
Mean		17	8
Deviation		0	1
1	Formaldehyde-treated wool	17	8
2		17	8
3		15	6
4		16	6
5		18	6
6		15	8
7		17	6
8		15	8
9		15	6
10		15	8
Mean		16	7
Deviation		1	1

TABLE XXI. EFFECT OF ACID IN TEN HOURS AT 25°C. ON THE WEIGHT, SULFATE SULFUR, AND TOTAL SULFUR OF FORMALDEHYDE-TREATED WOOL

Determination	Hydrochloric acid	Wool	Residue		Barium sulfate	Sulfate sulfur		Total sulfur	
number	normality	gram	gram	percentage of wool	gram	percentage of wool	percentage of residue	percentage of wool	percentage of residue
1	0.00	4.6020			1.5944			4.71	
2		4.5596			1.5459			4.65	
3		4.4580	4.4441	99.7	1.5350			4.73	
4		4.4342	4.4271	99.8	1.5005			4.65	
5		4.5896	4.5784	99.8					
6		4.3350			0.0304	0.70			
7		4.4307			0.0316	0.71			
Mean				99.8		0.71	0.71	4.69	4.70
Deviation				0.0		0.01		0.04	
1	6.00	4.5623			1.4020			4.22	
2		4.5381			1.3598			4.12	
3		4.5986			1.4036			4.19	
4		4.4460	4.3958	98.9					
5		4.4103	4.3455	98.5					
6		4.4120	4.3388	98.3					
7		4.4662			0.1170	0.36			
8		4.4416			0.1112	0.34			
Mean				98.6		0.35	0.35	4.18	4.24
Deviation				0.2		0.01		0.04	

TABLE XXII. EFFECT OF ACID IN TEN HOURS AT 25°C. ON THE NITROGEN OF FORMALDEHYDE-TREATED WOOL

Determination number	Hydrochloric acid normality	Wool gram	Hydrochloric acid milliliter 0.3315N	Sodium hydroxide milliliter 0.2387N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0.00	4.4560	200.00	61.35	16.24	
2		4.3490	200.00	65.20	16.34	
3		4.3980	200.00	62.45	16.37	
Mean					16.32	16.35
Deviation					0.05	
1	6.00	4.3820	200.00	65.80	16.17	
2		4.3945	200.00	66.75	16.06	
3		4.3513	200.00	67.42	16.09	
Mean					16.11	16.34
Deviation					0.04	

TABLE XXIII. EFFECT OF ACID IN TEN HOURS AT 25°C. ON THE STRENGTH OF WOOL AND FORMALDEHYDE-TREATED WOOL

Determination number	Fabric	Normality of hydrochloric acid 0.00 — Breaking strength of wet warp, pounds per inch	Normality of hydrochloric acid 6.00 — Breaking strength of wet warp, pounds per inch
1	Wool	8	2
2		8	2
3		8	0
4		8	2
5		8	2
6		8	2
7		8	2
8		8	2
9		8	
10		8	
Mean		8	2
Deviation		0	0
1	Formaldehyde-treated wool	8	4
2		6	4
3		8	4
4		8	4
5		8	4
6		8	4
7		8	4
8		7	4
9		7	
10		7	
Mean		8	4
Deviation		1	0

TABLE XXIV. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE WEIGHT, SULFATE SULFUR, AND TOTAL SULFUR OF FORMALDEHYDE-TREATED WOOL

Determination	Hydrochloric acid	Wool	Residue		Barium sulfate	Sulfate sulfur		Total sulfur	
number	normality	gram	gram	percentage of wool	gram	percentage of wool	percentage of residue	percentage of wool	percentage of residue
1	0.00	4.3705			1.4648			4.60	
2		4.4710	4.4306	99.1	1.5196			4.67	
3		4.3820	4.3358	99.0	1.4936			4.68	
4		4.5708			0.2173	0.65			
5		4.7942			0.2265	0.65			
Mean				99.0		0.65	0.66	4.65	4.70
Deviation				0.1		0.00		0.03	
1	0.25	4.5848	4.4872	97.9	1.3653			4.09	
2		4.7150	4.6122	97.8	1.4178			4.13	
3		4.6980	4.5641	97.2	1.3977			4.09	
4		4.5026			0.1481	0.45			
5		4.7243			0.1575	0.46			
Mean				97.6		0.46	0.47	4.10	4.20
Deviation				0.3		0.01		0.02	
1	0.50	4.3188	4.0713	94.3	1.2740			4.05	
2		4.5802	4.2204	92.1	1.3266			3.98	
3		4.5225	4.2130	93.2	1.3369			4.06	
4		4.6706			0.1126	0.33			
5		4.6110			0.1129	0.34			
Mean				93.2		0.34	0.36	4.03	4.32
Deviation				0.8		0.01		0.03	

TABLE XXIV. (Continued)

Determination number	Hydrochloric acid normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfate sulfur percentage of wool	Sulfate sulfur percentage of residue	Total sulfur percentage of wool	Total sulfur percentage of residue
1	0.75	4.6170	4.0500	87.7	1.2860			3.83	
2		4.8354	4.2882	88.7	1.3210			3.75	
3		4.5863	3.8560	84.1	1.2212			3.66	
4		4.6517			0.1040	0.31			
5		4.5776			0.0883	0.26			
Mean				86.8		0.29	0.33	3.75	4.32
Deviation				1.8		0.02		0.06	

TABLE XXV. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE NITROGEN OF FORMALDEHYDE-TREATED WOOL

Determination number	Hydrochloric acid normality	Wool gram	Hydrochloric acid milliliter 0.3315N	Sodium hydroxide milliliter 0.2387N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0.00	4.5624	200.00	56.10	16.24	
2		4.4650	200.00	59.60	16.34	
3		4.5783	200.00	54.20	16.33	
4		4.4138	200.00	63.70	16.22	
Mean					16.28	16.44
Deviation					0.05	
1	0.25	4.7130	200.00	54.30	15.85	
2		4.4481	200.00	66.60	15.87	
3		4.5363	200.00	62.60	15.86	
Mean					15.86	16.25
Deviation					0.01	
1	0.50	4.3283	200.00	80.65	15.23	
2		4.7065	200.00	63.50	15.22	
3		4.4081	200.00	75.45	15.35	
Mean					15.27	16.38
Deviation					0.06	
1	0.75	4.4458	200.00	92.50	13.93	
2		4.5780	200.00	85.55	14.04	
3		4.7474	200.00	79.40	13.97	
Mean					13.98	16.11
Deviation					0.04	

TABLE XXVI. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE STRENGTH OF WOOL AND FORMALDEHYDE-TREATED WOOL

Determination number	Fabric	Normality of hydrochloric acid 0.00	0.25	0.50	0.75
		Breaking strength of wet warp			
		pounds per inch	pounds per inch	pounds per inch	pounds per inch
1	Wool	8	0		
2		8	1		
3		8	2		
4		8	0		
5		8	0		
6		8	0		
7		8	0		
8		8	2		
9		8	2		
10		8	0		
Mean		8	1	<1	<1
Deviation		0	1		
1	Formaldehyde-treated wool	8	4	2	
2		8	4	2	
3		9	6	2	
4		8	4	2	
5		9	4	2	
6		9	4	2	
7		8	4	2	
8		8	4	2	
9		8	4	3	
10			4		
Mean		8	4	2	<1
Deviation		0	0	0	

TABLE XXVII. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE WEIGHT, SULFATE SULFUR, AND TOTAL SULFUR OF FORMALDEHYDE-TREATED WOOL

Determination number	Sodium hydroxide normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfate sulfur percentage of wool	Sulfate sulfur percentage of residue	Total sulfur percentage of wool	Total sulfur percentage of residue
1	0.00	4.6411	4.6315	99.8	1.5573			4.61	
2		4.4718	4.4584	99.7	1.5022			4.61	
3		4.6597	4.6390	99.6	1.5651			4.61	
4		4.4931	4.4746	99.6	1.4997			4.58	
5		4.4812			0.2209	0.68			
6		4.4307			0.2405	0.75			
Mean				99.7		0.72	0.72	4.60	4.61
Deviation				0.1		0.04		0.01	
1	0.05	4.8852	4.7500	97.2	1.0895			3.06	
2		4.6070	4.4740	97.1	1.0337			3.08	
3		4.8375	4.6887	96.9	1.0836			3.08	
Mean				97.1		0	0	3.07	3.16
Deviation				0.1				0.01	
1	0.10	4.6170	4.4181	95.7	0.8601			2.56	
2		4.7990	4.5953	95.8	0.8943			2.56	
3		4.6825	4.4793	95.7	0.8703			2.55	
4		4.6032	4.4119	95.8	0.8562			2.56	
Mean				95.8		0	0	2.56	2.67
Deviation				0.1				0.01	

TABLE XXVII. (Continued)

Determination number	Sodium hydroxide normality	Wool gram	Residue gram	Residue percentage of wool	Barium sulfate gram	Sulfate sulfur percentage of wool	Sulfate sulfur percentage of residue	Total sulfur percentage of wool	Total sulfur percentage of residue
1	0.15	4.4620	4.1790	93.7	0.7298			2.25	
2		4.6279	4.3337	93.6	0.7481			2.22	
3		4.4252	4.1362	93.5	0.7239			2.25	
Mean				93.6		0	0	2.24	2.39
Deviation				0.1				0.01	
1	0.20	4.6618	4.2302	90.7	0.7208			2.12	
2		4.7798	4.3715	91.5	0.7330			2.11	
3		4.4078			0.6843			2.13	
4		4.5764	4.1686	91.1	0.7103			2.13	
Mean				91.1		0	0	2.12	2.33
Deviation				0.3				0.01	
1	0.30	4.4701	3.7929	84.9	0.5706			1.75	
2		4.5401	3.8580	85.0	0.5745			1.74	
3		4.2833	3.6296	84.7	0.5385			1.73	
Mean				84.9		0	0	1.74	2.05
Deviation				0.1				0.01	
1	0.40	4.6704	3.6000	77.1	0.5216			1.53	
2		4.7580	3.6571	76.9	0.5136			1.48	
3		4.5584	3.4870	76.5	0.5018			1.51	
Mean				76.8		0	0	1.51	1.97
Deviation				0.2				0.02	

TABLE XXVIII. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE NITROGEN OF FORMALDEHYDE-TREATED WOOL

Determination number	Sodium hydroxide normality	Wool gram	Hydrochloric acid milliliter 0.3315N	Sodium hydroxide milliliter 0.2387N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0.00	4.5793	200.00	40.15	16.34	
2		4.5866	200.00	41.10	16.25	
3		4.7486	200.00	45.70	16.34	
4		4.5385	200.00	56.60	16.30	
Mean					16.31	16.34
Deviation					0.03	
1	0.05	4.6926	200.00	48.90	16.31	
2		4.7933	203.20	50.00	16.20	
3		4.6007	200.00	54.70	16.21	
4		4.4902	200.00	59.30	16.27	
Mean					16.25	16.70
Deviation					0.04	
1	0.10	4.5951	200.00	57.20	16.05	
2		4.5176	200.00	60.90	16.05	
3		4.6296	200.00	56.30	16.00	
4		4.5810	200.00	57.42	16.08	
Mean					16.05	16.75
Deviation					0.02	
1	0.15	4.7461	200.00	54.85	15.71	
2		4.5780	200.00	63.00	15.69	
3		4.4641	200.00	68.20	15.70	
Mean					15.70	16.76
Deviation					0.01	

TABLE XXVIII. (Continued)

Determination number	Sodium hydroxide normality	Wool gram	Hydrochloric acid milliliter 0.3315N	Sodium hydroxide milliliter 0.2387N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	0.20	4.5146	200.00	58.20	15.24	
2		4.6733	200.00	51.75	15.18	
3		4.8429	200.00	58.10	15.17	
Mean					15.20	16.68
Deviation					0.03	
1	0.30	4.3413	200.00	94.10	14.15	
2		4.5672	200.00	84.55	14.15	
3		4.6482	200.00	80.05	14.22	
Mean					14.17	16.69
Deviation					0.03	
1	0.40	4.7284	150.00	30.00	12.61	
2		4.6920	150.00	29.90	12.71	
3		4.5696	150.00	36.25	12.59	
4		4.6897	150.00	30.95	12.65	
Mean					12.64	16.46
Deviation					0.04	

TABLE XXIX. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE STRENGTH OF WOOL AND FORMALDEHYDE-TREATED WOOL

Determination number	Fabric	Normality of sodium hydroxide 0.00	0.05	0.10	0.15	0.20	0.30
		Breaking strength of wet warp					
		pounds per inch	pounds per inch	pounds per inch	pounds per inch	pounds per inch	pounds per inch
1	Wool	8	3				
2		8	2				
3		8	3				
4		8	4				
5		8	2				
6		9	2				
7		8	4				
8		9	4				
9		8	2				
10		9					
Mean		8	3	<1	<1	<1	<1
Deviation		0	1				
1	Formaldehyde-treated wool	10	6	4	2	2	
2		10	6	4	2	2	
3		10	6	4	3	2	
4		10	6	4	2	2	
5		10	6	4	2	2	
6		10	6	4	3	2	
7		10	5	4	2	2	
8		10	6	4	2	2	
9		10		4	3	2	
10		10		4	2	2	
Mean		10	6	4	2	2	<1
Deviation		0	0	0	0	0	

TABLE XXX. EFFECT OF 38 PERCENT SODIUM HYDROXIDE IN FIVE MINUTES AT 15°C. ON THE WEIGHT, SULFATE SULFUR, AND TOTAL SULFUR OF FORMALDEHYDE-TREATED WOOL

Determination	Wool	Residue		Barium sulfate	Sulfate sulfur		Total sulfur	
number	gram	gram	percentage of wool	gram	percentage of wool	percentage of residue	percentage of wool	percentage of residue
1	4.8721	4.7960	98.4	1.3420			3.78	
2	4.6066	4.5440	98.6	1.2636			3.77	
3	4.3755			0.0058	0.13			
Mean			98.5		0.13	0.13	3.78	3.84
Deviation			0.1		0.00		0.01	

TABLE XXXI. EFFECT OF 38 PERCENT SODIUM HYDROXIDE IN FIVE MINUTES AT 15°C. ON THE NITROGEN OF FORMALDEHYDE-TREATED WOOL

Determination number	Wool gram	Hydrochloric acid milliliter 0.3315N	Sodium hydroxide milliliter 0.2387N	Nitrogen percentage of wool	Nitrogen percentage of residue
1	4.5518	200.00	55.65	16.32	
2	4.4684	200.00	59.20	16.35	
3	4.4883	200.00	57.90	16.36	
4	4.5460	200.00	55.58	16.34	
Mean				16.34	16.59
Deviation				0.01	

TABLE XXXII. EFFECT OF 38 PERCENT SODIUM HYDROXIDE IN FIVE MINUTES AT 15°C. ON THE STRENGTH OF WOOL AND FORMALDEHYDE-TREATED WOOL

Determination number	Fabric	Percentage of sodium hydroxide: 0 — Breaking strength of warp: Conditioned, pounds per inch	0 — Wet, pounds per inch	38 — Conditioned, pounds per inch	38 — Wet, pounds per inch
1	Wool	17	6	17	
2		17	8	20	
3		17	8	19	
4		15	8	19	
5		17	8		
6		18	8		
7		17	7		
8		17	7		
Mean		17	8	19	<1
Deviation		0	0	1	
1	Formaldehyde-treated wool	17	8	8	
2		17	8	10	
3		15	6	10	
4		16	6	12	
5		18	6	12	
6		15	8	10	
7		17	6		
8		15	8		
9		15	6		
10		15	8		
Mean		16	7	10	<1
Deviation		1	1	1	

DISCUSSION OF RESULTS

The degradation of formaldehyde-treated wool in fifty-volume baths by hydrochloric acid, 0.00 and 6.00N, in ten hours at 25°C. (Tables XXI, XXII, and XXIII), by hydrochloric acid, 0.00, 0.25, 0.50, and 0.75 N, in one hour at 100°C. (Tables XXIV, XXV, and XXVI), and by sodium hydroxide, 0.00, 0.05, 0.10, 0.15, 0.20, 0.30, and 0.40N in ten hours at 40°C. (Tables XXVII, XXVIII, and XXIX), and by 38 percent sodium hydroxide in five minutes at 15°C. (Tables XXX, XXXI, and XXXII), is summarized in Table XXXIII.

Changes in the weight, composition, and mechanical failure of the formaldehyde-treated wool and a similar untreated wool (9, 114, 115) brought about by acid at 100°C. are contrasted in Graph 4; Graph 5 shows the protection formaldehyde provides wool against alkali at 40°C.

Formaldehyde protected the wool in acid at 100°C. as measured by changes in weight, nitrogen, non-sulfate sulfur, and wet strength; after one hour in 0.50N hydrochloric acid formaldehyde-treated wool retained 25 percent of its strength although the untreated wool had lost all its strength at this concentration.

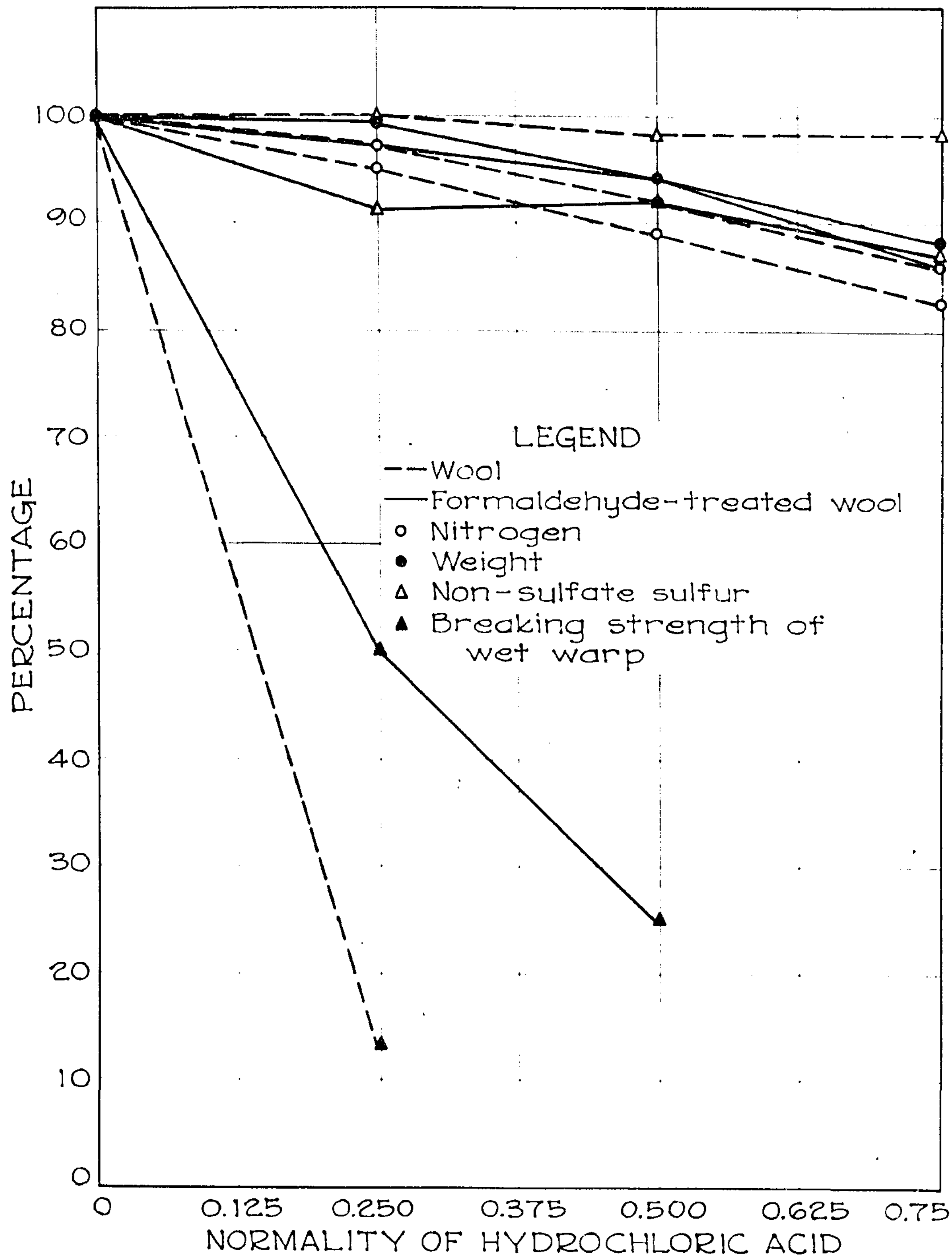
Formaldehyde-treated wool lost but one percent of weight in ten hours at 25°C. in 6.00N hydrochloric acid, as compared with a loss of five percent by wool. The wet strength of the formaldehyde-treated wool was then fifty percent of its original strength, that of the untreated wool but twenty percent. The ratio of sulfur to nitrogen was lowered in none of the acid baths.

Residues of the formaldehyde-treated wool from ten hours' immersion in dilute alkali at 40°C. were nearly constant in total nitrogen, greater in weight than those of wool, and of a measurable wet strength, two pounds, at 0.20N, a concentration four times that beyond which the untreated wool failed. The graph of the non-sulfate sulfur of the formaldehyde-treated wool, a decreasing logarithmic function of the concentration of alkali, $y = ax^B$, coincides with that of wool at 0.05 and 0.10N alkali. The formaldehyde-treated wool's ratios of sulfur to nitrogen decreased with increasing concentration of alkali.

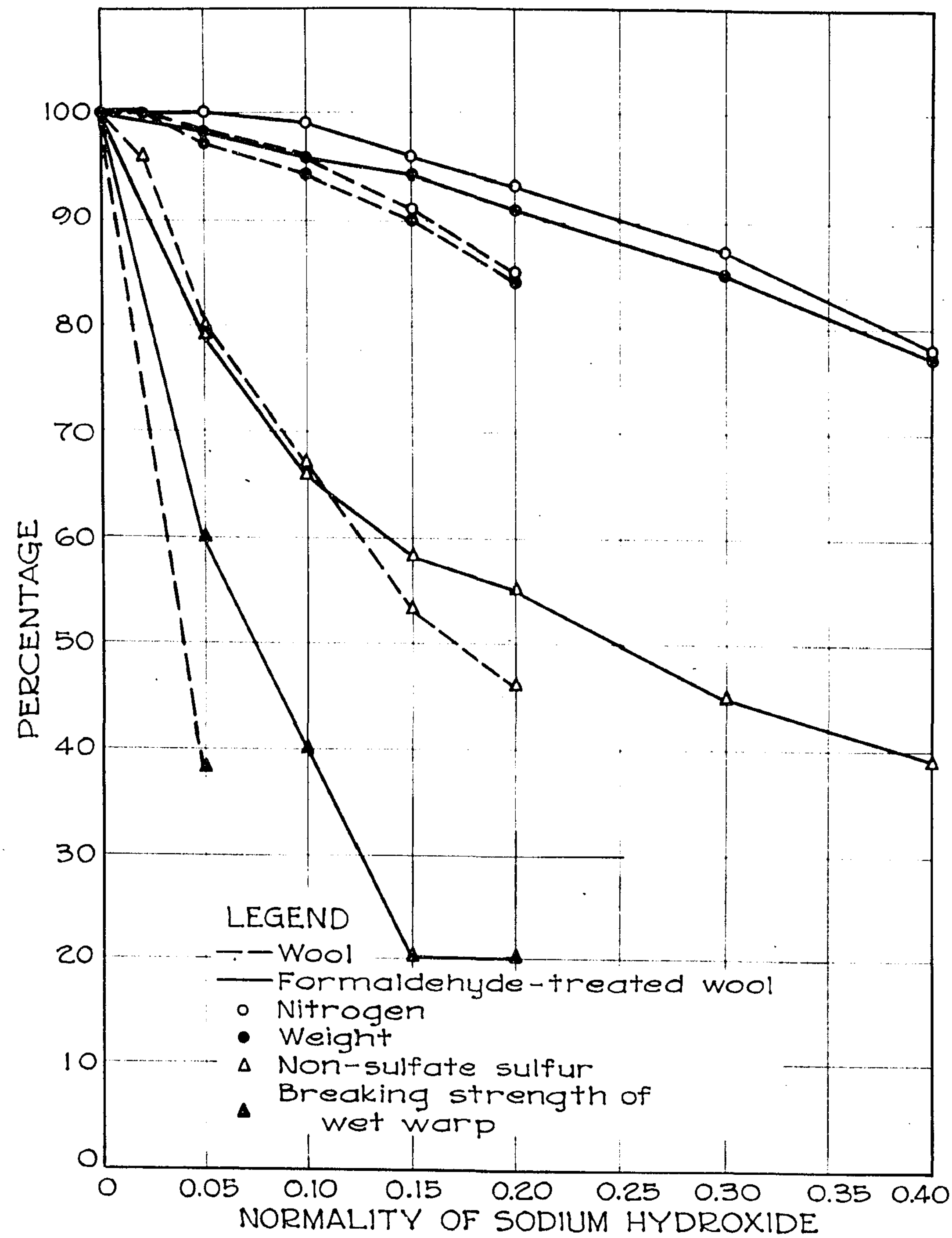
Percentage losses of non-sulfate sulfur, weight, and wet strength in 38 percent alkali were the same for the formaldehyde-treated wool as for the untreated wool; the total nitrogen of the formaldehyde-treated wool was not changed by mercerization (9, 10).

TABLE XXXIII. EFFECT OF ACID AND ALKALI ON THE WEIGHT, TOTAL SULFUR, SULFATE SULFUR, NITROGEN, AND STRENGTH OF FORMALDEHYDE-TREATED WOOL.

Hydrolytic agent		Time	Temperature	Weight	Total sulfur	Sulfate sulfur	Nitrogen	Ratio of non-sulfate sulfur to nitrogen	Breaking strength of wet warp
	normality	hour	°C.	percentage of wool	percentage of wool	percentage of wool	percentage of wool		pounds per inch
Hydrochloric acid	0.0000	10	25	99.8	4.69	0.71	16.32	0.24	8
	6.0000			98.6	4.18	0.35	16.11	0.24	4
	0.0000	1	100	99.0	4.65	0.65	16.28	0.25	8
	0.2500			97.6	4.10	0.46	15.86	0.23	4
	0.5000			93.2	4.03	0.34	15.27	0.24	2
	0.7500			86.8	3.75	0.29	13.98	0.25	<1
Sodium hydroxide	0.0000	10	40	99.7	4.60	0.72	16.31	0.24	10
	0.0500			97.3	3.07	0.00	16.25	0.19	6
	0.1000			95.8	2.56	0.00	16.05	0.16	4
	0.1500			93.6	2.24	0.00	15.70	0.14	2
	0.2000			91.1	2.12	0.00	15.20	0.14	2
	0.3000			84.9	1.74	0.00	14.17	0.12	<1
	0.4000			76.8	1.51	0.00	12.64	0.12	<1
	9.4988	0.25	15	98.5	3.78	0.13	16.34	0.21	<1



GRAPH 4. EFFECT OF ACID IN ONE HOUR AT 100°C. ON THE WEIGHT, NITROGEN, NON-SULFATE SULFUR, AND WET STRENGTH OF WOOL AND FORMALDEHYDE-TREATED WOOL



GRAPH 5. EFFECT OF ALKALI IN TEN HOURS AT 40°C. ON THE WEIGHT, NITROGEN, NON-SULFATE SULFUR, AND WET STRENGTH OF WOOL AND FORMALDEHYDE-TREATED WOOL

SUMMARY

1. Degradation of plain-woven wool, treated with one percent formaldehyde for one hour at 70°C., by 6.00*N* hydrochloric acid in ten hours at 25°C., 0.2500 to 0.7500*N* hydrochloric acid in one hour at 100°C., 0.0500 to 0.4000*N* sodium hydroxide in ten hours at 40°C., and 38 percent sodium hydroxide for five minutes at 15°C., has been measured by the weight, nitrogen, sulfur, and wet warp breaking strength of the residual wool.

2. The decrease in weight and strength was less for formaldehyde-treated wool than for wool when treated with 6.00*N* hydrochloric acid at 25°C.

3. Formaldehyde protected wool from loss in weight, nitrogen, sulfur, and wet strength when treated with acid at 100°C; formaldehyde-treated wool retained 25 percent of its wet strength after one hour at 100°C. in 0.5000*N* hydrochloric acid although wool showed no measureable strength when so treated.

4. The ratio of sulfur to nitrogen in the residual formaldehyde-treated wool remained constant on treatment with acid.

5. Formaldehyde protected wool from loss in weight and wet breaking strength when treated with dilute alkali for ten hours at 40°C. The wet strength of wool was completely

destroyed after treatment in 0.1000N sodium hydroxide while formaldehyde-treated wool still retained 20 percent of its strength after treatment in 0.2000N sodium hydroxide.

6. The nitrogen of the residual formaldehyde-treated wool remained constant. The loss in non-sulfate sulfur of formaldehyde-treated wool coincided with that of wool at 0.0500 and 0.1000N alkali but was less at greater concentrations of alkali.

7. The ratio of sulfur to nitrogen in the residual formaldehyde-treated wool decreased with increasing concentration of alkali.

8. The loss of sulfur, weight, and wet strength in five minutes at 15°C. in 38 percent sodium hydroxide was the same for formaldehyde-treated wool as for wool; the total nitrogen of formaldehyde-treated wool was unchanged by this treatment.

III. COMPARISON OF THREE TEXTILE DETERGENTS

REVIEW OF THE LITERATURE

Many theories have been proposed by different investigators to explain why soap, the most common detergent, cleans. In 1880 Hofmeister (40) and in 1895 Krafft and Wiglow (40) described solutions of soap as colloidal. Since their time many investigations have supported the colloidal theory and it is now accepted as the main explanation for the detergent action of soap (90, 93, 151, 168). McBain has stated that soap in most aqueous solutions exists as a colloidal electrolyte (40).

Factors important in the detergency of textiles are a) the solubility of the detergent, b) its ability to form a colloidal solution, c) its emulsifying power which depends on low surface tension, d) its wetting power, e) its lubrication of textile and impurities, f) its deflocculation of dirt, g) and perhaps its foaming power (8, 26, 27, 40, 53, 55, 98, 99, 109, 128, 142, 145, 154, 164, 169).

Some methods which have been used in evaluating detergents are:

1. Measurement of surface tension against air by a) capillary tube, b) drop number, c) bubbling, or d)

the froth produced under definite conditions (8, 23, 60, 145, 151, 152, 173).

2. Measurement of surface tension against fat, paraffin, or benzene by drop number or degree of emulsification (16, 36, 61, 62, 89, 98, 100, 110, 121, 130, 136, 145, 151).

3. Measurement of protective action by gold number (48, 122, 123, 145).

4. Measurement of comparative rate of sedimentation or protective action during filtration (23, 40, 95, 145).

5. Direct washing experiments with specially soiled textiles under controlled conditions (6, 11, 30, 50, 64, 65, 81, 86, 114, 140, 151, 153, 158, 159, 170).

Soap as a detergent

Fall in 1927 observed that the optimal concentration of olive-oil soap for suspending fine clay, lampblack, or manganese dioxides is between 0.156 and 0.625 percent (40). Vincent in the same year defined the optimal concentration of soap for the suspension of solids as between 0.2 and 0.4 percent and the optimal concentration for emulsification of fat as between 0.05 and 0.10 percent; he recommended a temperature of 40°C. since emulsions tended to break at higher temperatures (168). Mullin described the optimal concentration as below 0.5 percent (108). Rhodes and Brainard in

1929 observed that variation of temperature between 20 and 60°C. had little effect on the detergent action of soap, that the maximal effect occurred in 7.5 minutes, and that increasing the concentration of soap above 0.25 percent produced little change in its detergent action (135).

The detergent action of soap seems to vary with the pH of the solution (72, 92, 96, 105, 106, 108, 130, 131). Rhodes and Bascom found that the detergent action of an approximately neutral soap, at the optimal concentration of 0.25 percent and optimal temperature of 40°C., at first increased and then decreased as the alkalinity of the solution was increased (134). They as well as other investigators have reported maximal detergent effect at pH of 10.7 (96, 109). Jaeger and Coffman recommended a pH of 13 for cotton, a pH of 10 to 11 for wool, and a pH of 9 for degumming silk (68). Elöd suggested a pH of 7 to 8 for laundering viscose rayon (37) and Elöd and Rudolph stated that damage to wool was minimized by washing at a pH of 4.9 (38).

In 1919 Woodmansey studied the absorption and retention of soap by textiles and observed that wool serge in 48 hours absorbed 3.6 percent of fat acid, spun silk 1.8 percent, and cotton cambric 0.4 percent from a 0.5 percent solution of castile soap. He noted that the base absorbed from a solution of soap was greater than that of fat acid and that absorption increased with duration of immersion, temperature, and concentration of soap (176). In 1935 Neville, Harvey and Harris reported that silk and wool absorbed soap and selectively absorbed alkali, and that cotton absorbed but a relatively small amount of soap and showed no selective absorption (111). Powney and Addison (129) in 1938 stated that wool absorbed little alkali below a pH of 10.

Matthews in 1905 studied the effect of hot water and soap on unscoured woolen yarns containing six percent grease and dirt. He found that wool treated with water at 60°C. for twenty minutes lost 37 percent of its tensile strength and 2.2 percent in weight; at 100°C. the wool lost 36 percent in strength and 3.4 percent in weight. Wool treated with five grams of soap per liter of solution at 18°C. for twenty minutes lost 41 percent in strength and 4.2 percent in weight; at 100°C. it lost 62 percent in strength and 5.9 percent in weight (94).

Barmore studied the effect of temperature and pH of scouring bath on wool. He found that an increase of fourteen degrees Centigrade at the same pH doubled the loss in strength of the wool. A decrease in strength was noted at pH of 4.8, although the decrease was very slight until pH of 7. He proposed as the most suitable conditions for scouring wool, 38 to 55°C., 0.3 to 0.4 percent soap, and four to five minutes' treatment (4).

King in 1935 described wool as chemically attacked by water above 50°C. and at a lower temperature in the presence of alkali. He considered a pH of 9 to 10 optimal for felting as well as for scouring (82). Harrison observed that a pH of 12 at 49°C. had no degrading effect on wool but that more alkaline solutions yellowed and degraded it (57).

Silicated soap as a detergent

The suitability of silicates as detergents for textiles has been a controversial topic for many years. Silicates have detergent properties because of their capacity for wetting, emulsifying, deflocculating, and dissolving (3, 28, 145, 151, 164). The adsorptive and emulsifying powers of silicates are the chief reason for their use in soaps. Fall has listed in decreasing order of their dirt-suspending powers 1) sodium silicate, 2) sodium phosphate, 3) sodium hydroxide, and 4) sodium carbonate (40).

Many investigators have considered silicate a valuable builder for soap because it improves the soap's emulsifying power, controls the alkalinity of its solution, prevents the formation of alkaline earth soaps, iron stains, and the redeposition of suspended dirt on the textile (6, 20, 21, 29, 44, 50, 67, 83, 101, 102, 116, 125, 127, 132, 136, 141, 150, 147, 149, 156, 165, 160, 163, 167).

Vincent described a soap eighty percent silicate as of merit for general use (168). Haas in 1931 reported that commercial detergents contained from 0.13 to 6.95 percent silicon dioxide (54); Snell reported the most common ratio of builder to soap as one to three (146). Feld stated that a detergent solution containing six to ten grams calcined soda, six to ten grams of curd soap, and one to two grams of water glass was suitable for textiles (42); Snell and Moss reported the ratio of sodium oxide to silica as five to three in another detergent (148).

Grün and Jungman in 1918, while studying the effect of soap, sodium carbonate, and sodium silicate on linen and cotton, observed that sodium silicate showed a distinctly degrading action (52). Vail in 1922 reported that sodium silicate bleached cotton but did not affect its strength (161). Several other authors have pointed out the bleaching action of silicate on cotton (116, 126, 164). Heerman in 1923 reported that cotton lost less than five percent but linen fourteen percent in weight when washed fifty times in a detergent containing silicate (58). Huebner and Malwin impregnated cotton with one percent soap and determined its ripping and tensile strain; the latter was slightly decreased and the former increased (66). King in 1923 observed that cotton treated with a silicate of the composition, $Na_2O \cdot 3SiO_2$, increased in strength after thirty washings while linen decreased twice as much in strength with silicate as with soap (80). More than ten percent alkaline silicate has been reported as destructive to textiles (171). One percent alkaline silicate has also been reported as highly degrading (71).

Vail in 1924 reported that under ordinary working conditions approximately fifty washings were required to raise the ash of the residual textile to two percent (165). In 1929 he reported that after 100 launderings in silicate there was a six percent deposit on the fiber (162). Haas in 1931 also noted that waterglass increased the ash of the residual fibers (54).

Dischendorfer in 1925 studied the effect of soap, equal weights of soap and sodium carbonate, and a perborate-silicate soap on textiles. The strengths of linen after two, ten, and twenty washings with soap were 99, 95, and 92 percent, respectively; with perborate-silicate soap the corresponding values were 94, 76, and 66; for cotton with soap the corresponding values were 97, 95, and 93; and with perborate-silicate soap 98, 92, and 85 percent (32).

Raaschou and Larsen in 1928 heated cotton from 50 to 100°C. for thirty minutes and then boiled it for thirty minutes in either one percent waterglass or one percent soap. In fifty treatments waterglass increased the ash 43 percent, soap 4.7 percent. A cotton fabric of medium weight lost thirteen percent in strength with waterglass and 24 percent with soap; one of light weight lost 31 percent in strength with waterglass and 42 percent in soap. A mixture of 0.33 percent soap, 0.33 percent sodium carbonate, and 0.04 percent waterglass in hard water lowered the strength of cotton but slightly while the same mixture without the waterglass resulted in considerably greater loss in strength (133).

McGowan in 1930 washed cotton, linen and wool fabrics ten times at 40°C. for ten minutes and reported the breaking strength (warp X filling in pounds) of the washed fabrics: 1. Cotton in a) water 922.72, b) silicated soap 851.64, c) carbonated granular soap 806.52; 2. linen in a) water 1514.36, b) silicated soap 1432.05, c) carbonated soap 1368; 3. wool in a) water 400.20, b) silicated soap 359.7, and c) carbonated soap 350.20 (97).

Ohl in 1934 compared the action on wool of commercial calcined soap, Lux Soap Flakes and Persil, a perborate-silicate washing compound. He found that 0.5 percent Persil effected a degree of cleansing in a single washing at 20°C. comparable to a washing at 45°C. for the other detergents. After a number of washings at 45°C. degradation of the wool occurred, especially with calcined soap which made the handle harsh (115). Ohl in 1934 observed that viscose rayon immersed in 0.02 percent waterglass swelled less and was of higher strength (117). Foulon in 1936 stated that the loss in strength of cotton in soap-sodium silicate was less than in soap alone (45). In the same year Brettschneider stated that waterglass was degrading to textiles (15) although Kiefer questioned whether Brettschneider's results could always be attributed to waterglass (75).

Ohl in 1937 treated wool, cotton, and linen ten times with a solution of sodium silicate and found that in a 0.1 percent solution cotton lost 2.2 percent in strength, wool 5 percent and linen 9 percent; in a 0.2 percent solution cotton lost 2.5 percent, wool 5.8 percent, and linen 10.8 percent; in one percent solution cotton lost 2.85 percent, wool 0.66 percent and linen 12.36 percent (118). Oesterling in 1938 washed a standard soiled cotton fabric in sodium hydroxide, trisodium phosphate, sodium carbonate, and sodium metasilicate in concentrations from 0.007 to 0.1713 percent sodium oxide and found that the loss in strength of cotton after fifty washings was negligible, less than 5 percent in all cases. He reported that the most efficient detergent solution at 48.89°C. consisted of 0.1 percent soap and 0.0143 to 0.0282 percent builder, calculated as sodium oxide (114). Bergell in 1939 observed that 0.25*N* metasilicate, in one hour at 50°C., was more degrading to wool than was 0.125*N* sodium hydroxide (7).

Sulfated alcohols as detergents

In 1913 Reychler reported that cetyl sulfonic acid and sodium cetyl sulfonate possessed properties like those of soap. In 1923 Adams described cetyl benzene sulfonic acid as like soap (25). In the last ten years a great development of non-soap detergents has occurred and numerous patents have been issued, most for the production of sulfates and sulfonates (5, 9, 12, 19, 22, 25, 31, 69, 87, 88, 103, 107).

For the production of alkyl sodium sulfates, long-chain primary aliphatic alcohols formed by the catalytic hydrogenolysis of fats are sulfonated and the resulting mono-alkyl esters are neutralized to the corresponding sodium salts (2, 17, 41, 76, 104, 113, 138). Recently a method for the production of these detergents from petroleum has been suggested (120).

The esters of secondary alcohols have been reported as showing little or no detergent action (87, 88). Wilkes and Wickert found secondary alkyl sulfates somewhat inferior to the primary alkyl sulfates as scouring agents but decidedly superior as wetting agents (175).

Commercial sulfated alcohols contain but thirty to fifty percent of active detergent along with some unchanged alcohol and forty to sixty percent of sodium sulfate, sodium phosphate, or sodium carbonate. They have excellent wetting, dispersing, and emulsifying powers, they do not hydrolyze, are stable to acid, alkali, and hard water, dissolve completely and rapidly in water, and are practically neutral in solution (14, 34, 41, 49, 59, 74, 84, 87, 137, 155, 175, 177).

These sulfated alcohols have been recommended for scouring wool stock, yarns, and fabrics, cotton and rayon, and for wetting agents in desizing, bleaching, mercerizing, weighting, mordanting, and dyeing textiles (13, 41, 84, 143, 155, 174).

The unsaturated sulfated alcohols have greater detergent properties than the saturated. The wetting, dispersing, and leveling powers of the sulfated alcohols are greatest for those of twelve carbon atoms and decrease as the number of carbons increases; the detergent property, interfacial tension, and lathering power, reach a maximum at sixteen carbon atoms (18, 34, 43, 70, 73, 88, 124). The solubility of these sulfated alcohols decreases with an increase in the number of carbon atoms. Their solubilities in water are more affected by temperature than those of the corresponding soaps; sodium lauryl sulfate is twenty percent soluble at room temperature, sodium oleyl sulfate is but one to two percent soluble at room temperature although fifteen percent soluble at 48.9°C., and sodium stearyl sulfate, not soluble at room temperature, is soluble at 48.9°C. (88).

The only metal ions forming insoluble salts with lauryl sulfate are aluminum, iron, lead, and tin and these metal alkyl sulfates do not stain textiles. The solubility of these salts increases rapidly with temperature. The sulfated alcohols are just as effective in hard water as in distilled since they appear to act as protective colloids, keeping alkaline earth salts in suspension (157). Lindner found that sodium oleyl sulfate dispersed calcium soaps and suggested the use of a mixture, one part soap and 0.7 part sodium alkyl sulfate (91). Kuchertz stated that sulfated alcohols have little dispersive action with lime soaps (85). Hannay in 1934 corroborated this statement (56).

Vene reported that solution of sodium alkyl sulfates was necessary for detergency, and that their optimal concentration ranged between 0.1 to 0.25 percent at 50°C. Contrary to other reports Vene observed that sodium cetyl sulfate had as high detergent power as lauryl and oleyl sulfates at moderate temperatures (166).

Evans has compared the sulfates and the sulfonates and has found that cetyl sodium sulfate surpasses cetyl sulfonate in solubility, wetting power, and detergent action. He has also described sodium cetyl sulfate as a much better detergent than sodium dodecyl sulfate (39).

Weltzien and Ottensmeyer observed that commercial products gave greater lowering of surface tension than purified detergents and showed that this was due to the electrolyte present (172). Kimura and Taniguti stated that the addition of forty to 200 percent sodium sulfate lowered the surface tension and interfacial tension against kerosese of of 0.01 to 0.1 percent solutions of sodium alkyl sulfates (77, 78). Jones noticed that the hydrolysis of sodium alkyl sulfates in acid solutions was decreased by sodium sulfate (70).

Kimura and Taniguti reported that sodium alkyl sulfates containing from sixteen to eighteen carbon atoms were completely hydrolyzed by boiling for ninety minutes in 2N hydrochloric acid; those containing fourteen carbons by boiling for four hours in 3N hydrochloric acid; and those containing twelve carbons by boiling for three hours in 2N hydrochloric acid (79).

Hoff in 1932 stated that alcohol sulfonates left worsted textiles smooth and soft after a short period of washing and protected woolen fibers against excessive action of alkali (63). Work done in this laboratory showed that an aromatic sulfonate produced more shrinkage of wool in hard water than did soap (33).

In 1933 Götte, comparing different sodium alkyl sulfates by washing tests, observed that those of shorter chain were more effective in hard water at low temperatures and those of longer chain were more effective at higher temperatures. He noted that the "washing value" of all the sodium alkyl sulfates in alkaline solution greatly exceeded that of soap, while in neutral or acid solution it equalled or exceeded that of soap (50).

Gerstner in 1933 reported washing tests in which wool dyed with acid dyes was washed at 50° and 80°C. with soap-soda mixtures and sodium lauryl sulfate-soda mixtures. The change in shade and the bleeding of dyed wool were less with the sodium alkyl sulfate-soda mixture (47).

Neville, Jeanson, and Smith in the same year stated that wool adsorbed very little oleyl sulfate above pH 6.5 but that below this value the amount adsorbed increased rapidly to 30.8 percent at a pH of 1 (112).

Adams in 1937 noted that a wool fabric, 100 yards by forty inches, adsorbed 2.3 pounds of soap or 0.17 pounds of cetyl sodium sulfate while cotton adsorbed 0.17 pounds of soap or 0.17 pounds of cetyl sodium sulfate (1).

Szego and Beretta in 1934 compared Lux, sodium oleate, Igepon T, (condensation product of a fat acid and an amino sulfonic acid) and sodium cetyl sulfate by means of washing tests and on the basis of one for the detergency of water computed these indexes, 3.92 for Lux, 2.63 for sodium oleate, 3.57 for Igepon T, and 5.97 for sodium cetyl sulfate (153).

Schumann in 1934 stated that neither sodium carbonate, soap, nor sodium alkyl sulfates degraded wool (139). Franz found no great difference in the efficiency of the new non-soap detergents as compared with soap in washing wool at

40° to $45^\circ C$. and a pH of 7 to 10. He reported that the new textile detergents were more easily rinsed from wool and were of no felting action (46). Ohl in 1935 noted that the alkyl sulfates were inferior to soap for removing certain dirt and stains from fabrics (119).

EXPERIMENTAL PROCEDURE

Materials*

1. Ethyl alcohol. Ninety-five percent. U. S. Industrial Chemical Company.

2. Fabrics. The plain-woven fabrics, 1) unbleached cotton broadcloth shirting, 2) regenerated-cellulose rayon crepe, 3) cellulose-acetate rayon faille taffeta, 4) silk crepe, 5) wild-silk pongee, and 6) wool homespun are described by analysis in Table XXXVI. Swatches of the new and washed fabrics are mounted in the appendix.

The silk and the wool fabrics were prepared for experimental use in this laboratory. A raw silk crepe was degummed by boiling it for one hour in one hundred volumes of ten percent neutral olive-oil soap. After rinsing the residual silk two or three times in distilled water, the degumming process was repeated. The degummed silk was then rinsed at room temperature and boiled for fifteen minutes in distilled water; this latter procedure was repeated three times with intermediate rinsings.

An unscoured wool fabric (of no selenium but containing 7.2 percent extractable fat and wax) (33) woven in 1936 from yarns of carbonized New Zealand wool and

* Materials not listed here have been described before.

Australian tops (mean length 3.3 inches) lubricated with an emulsion of lard oil, hot water, glycerol, and borax at Biltmore Industries Incorporated, Asheville, N. C., was scoured in eighty volumes of a 0.5 percent neutral olive-oil soap for fifteen minutes at room temperature and rinsed in distilled water for fifteen minutes. This scouring was repeated twice and the wool rinsed until the rinse no longer foamed.

3. Phenolphthalein. General Chemical Company.

4. Silicated soap. The analysis of this commercial granular soap, 78.9 percent anhydrous soap, 6.1 percent total silica, 1.3 percent alkaline silicate, 3.7 percent matter volatile at 105°C., 9.1 percent combined alkali, of no free acid or alkali, unsaponified or unsaponifiable matter, of 5.3 percent water-insoluble matter, 15.4 percent alcohol-insoluble matter the aqueous extract of which contained the equivalent of 5.1 percent sodium oxide, of an acid number of 223 and a titer of 35°C. is presented in Table XXXIV.

5. Soap. Table XXXIV also presents the analysis of this commercial flaked olive-oil soap, 98.3 percent anhydrous soap, 0.8 percent matter volatile at 105°C., 9.9 percent combined alkali, of no free acid or alkali, alcohol-insoluble, unsaponified or unsaponifiable matter, and of an acid number of 198 and a titer of 12.9° Centigrade.

6. Sulfated alcohol. The analysis of the commercial

sulfated alcohol of 4.6 percent total organic sulfur (computed from sulfuric acid-treated ash), 4.0 percent organic sulfate sulfur, 1.8 percent ether-soluble matter, and 46.8 percent alcohol-insoluble matter, and 48.0 percent sodium sulfate (computed from total sulfate sulfur and organic sulfate sulfur) is presented in Table XXXV.

Methods*

A. Washing of fabrics

Each of the cellulose, regenerated-cellulose, cellulose-acetate, silk, wild silk, and wool fabrics was washed by hand in fifty volumes of 0.5 percent (five grams per liter of solution) aqueous solution of soap, silicated soap, or sulfated alcohol for five minutes at room temperature, rinsed in distilled water until the rinse no longer foamed and dried in air and diffused light at room temperature without pressing.

The residual fabrics were analyzed after ten, twenty, thirty, forty, and fifty washings. Walter has stated that twenty to fifty repeated washings are sufficient for a practical test (170); Kind has raised this lower limit to twenty-five (81). All the fabrics were analyzed for ash, absorbtion of light, shrinkage, wet strength and elongation at breaking load, and weight; the silks and wool were analyzed for nitrogen;

* Other methods have been described in Part I.

the wool for total sulfur and the wool and the silks washed with sulfated alcohol for sulfate sulfur; the cellulose acetate for acetyl. Chemical analyses are reported on the basis of the residual fabric dried at 105 to 110°C. until constant within 0.0004 gram.

B. Analysis of soap (144)

1. Combined alkali

Five grams of air-dry soap were dissolved in 100 milliliters of water, dilute sulfuric acid was added in slight excess, and the solution was heated at 60°C. until the fat acids separated. The fat acids were extracted with two twenty-milliliter portions of ether which were combined and washed free of acid with distilled water. The ethereal solution of the fat acids was transferred to a weighed dish, 100 milliliters of neutral ethyl alcohol were added, and the fat acids were titrated with standard sodium hydroxide using phenolphthalein as indicator. In the case of the silicated soap, the alcohol of the filtrate obtained in the determination of matter insoluble in alcohol was evaporated on a steam bath, the residue dissolved in water, and the fat acids extracted as described before. The combined alkali was computed from three parallel determinations as percentage of sodium oxide in the air-dry soap.

2. Total anhydrous soap

The solution from the determination of combined alkali was evaporated and the residue dried to constant weight at 105°C. in an electric oven. The percentage of anhydrous soap in the air-dry soap was computed from three parallel determinations.

3. Matter volatile at 105°C.

A five-gram sample of air-dry soap was dried to constant weight at 105°C. in an electric oven. Loss in weight in three (soap) or four (silicated soap) parallel determinations was computed as percentage of the air-dry soap.

4. Total matter insoluble in alcohol

A five-gram sample of air-dry soap was digested on a steam bath with 200 milliliters of ethyl alcohol, filtered, washed with fresh portions of alcohol, dried at 105°C., and weighed. The residues from two parallel determinations of the silicated soap were computed as percentage of the air-dry silicated soap.

5. Matter insoluble in water

The matter insoluble in alcohol was extracted with water at 60°C., dried at 105°C. for three hours, and weighed. The residues from two parallel determinations of the silicated soap were computed as percentage of the air-dry silicated soap.

6. Total alkalinity of matter insoluble in alcohol

The filtrate from the extraction with water was titrated with 0.3324<u>N</u> hydrochloric acid using Methyl Orange as indicator. The alkalinity was computed as percentage of sodium oxide in the silicated soap from the mean of four parallel determinations.

7. Total silica

Two grams of air-dry soap were ignited in a platinum crucible at a low temperature. Fifty milliliters of water were added to the residue, the solution was acidified and ten milliliters of concentrated hydrochloric acid were added in excess. This solution was evaporated to dryness on the steam bath, the residue was moistened with concentrated hydrochloric acid and allowed to stand ten minutes. Then 25 milliliters of hot water were added, the solution was heated a few minutes, filtered, and the filtrate evaporated to dryness. This treatment was repeated and the combined residues were ignited to constant weight. The total silica was computed from four parallel determinations as percentage of the air-dry silicated soap.

8. Alkaline silicate

The alkaline silicate was determined by acidifying and evaporating the filtrate from the matter insoluble in water and proceeding as in the determination of total silica. The percentage of alkaline silicate in the air-dry silicated soap was computed from two parallel determinations.

9. Acid number of fat acids

Fifty grams of soap were dissolved in 300 milliliters of hot water, 150 milliliters of 2N sulfuric acid were added and the liberated fat acids were extracted in a separatory funnel with 120 milliliters of ether. This extract was then washed free of acid with concentrated sodium chloride. Anhydrous sodium sulfate was added to the ethereal solution which, after standing until clear, was filtered and evaporated by heating the flask to 50°Centigrade.

Two grams of the fat acids were dissolved in 25 milliliters of neutral 95 percent ethyl alcohol and titrated with standard sodium hydroxide using phenolphthalein as indicator. The acid number was computed as milligrams of potassium hydroxide per gram of fat acid. Four parallel determinations were made for soap, five for silicated soap.

10. Titer

The fat acids which had been heated above their melting point were transferred to a titer tube, 25 by 100 millimeters, fitted in the cork of a wide-mouthed bottle. The fat acids were stirred with a thermometer graduated in tenths of a degree until the mercury remained stationary for thirty seconds. Three determinations were made for each soap.

C. Analysis of sulfated alcohol (10)

1. Alcohol-insoluble matter

A five-gram sample of the air-dry detergent was digested on a steam bath with 200 milliliters of ethyl alcohol, filtered, washed with alcohol, dried at 105°C., and weighed.

The residues from three parallel determinations were computed as percentage of the air-dry detergent.

2. Ether extract

A five-gram sample of air-dry detergent was extracted with diethyl ether in a Soxhlet extractor for 24 hours, the residue weighed and the ether extract computed by differences from two parallel determinations.

3. Organic sulfate sulfur

Fifty milliliters of 0.5N hydrochloric acid were added to two grams of sulfated alcohol, neutral to Methyl Orange, and the solution was refluxed on a boiling water bath for two hours. After adding thirty grams of sodium chloride and twenty milliliters of ether the hydrochloric acid and the sodium hydrogen sulfate formed by hydrolysis were titrated with standard sodium hydroxide using Methyl Orange as indicator. Organic sulfate sulfur was computed from four parallel determinations as percentage of air-dry detergent.

4. Total sulfate sulfur

The total sulfate sulfur in the solution from the determination of organic sulfate sulfur was then determined by precipitating and weighing the barium sulfate formed from it. Total sulfate sulfur as percentage of air-dry detergent was computed from two parallel determinations.

5. Total sulfur

The total sulfur was determined by the Parr bomb method using 0.3 gram of air-dry detergent. Total sulfur was computed from three parallel determinations as percentage of the air-dry detergent.

6. Sulfuric-acid treated ash

A five gram sample of air-dry sulfated alcohol was ignited in a muffle furnace at dull red heat, the ash moistened with sulfuric acid, and ignited to constant weight. Sulfuric-acid treated ash as percentage of air-dry detergent was computed from three parallel determinations.

D. Analysis of fabrics

1. Absorption of light

This determination was made with a Pfaltz and Bauer Reflectometer Universal Model MU using a lamp for one hour and a voltage of 3.8. With photocell insert on the white standard the pointer of the microammeter was set on zero of the scale by means of the regulating resistances; with photocell insert on the black standard the pointer was set on 100 by adjustment of the sensitivity regulator. Resetting and readjustment were continued until the pointer showed zero on the white and 100 on the black without adjustment. Several thicknesses of fabric were clamped as tightly as possible in a frame for each photometric reading. The mean of five observations is reported as the absorption of light by the fabric.

2. Acetyl

Approximately two grams of cellulose-acetate rayon were heated to constant weight at 105°C. and immersed in 25 milliliters of 1:1 alcohol-water for fifteen hours. An equal volume of normal sodium hydroxide was then added and after 48 hours the excess alkali was titrated with standard hydrochloric acid using phenolphthalein as indicator (35).

3. Breaking strength and elongation at breaking load

The new fabrics were tested both wet and conditioned for warp and filling breaking strength; the washed fabrics for wet warp breaking strength. The conditioned specimens were kept for one week at 65±2 percent relative humidity and 70°± 2° F. before testing. The specimens were immersed in distilled water for five minutes before testing wet. The breaking strengths were all determined within two days. The mean breaking strength per yarn was computed and used as a basis for computing change in breaking strength of fabric upon washing.

Actual elongation at breaking load was measured to one-ninth inch on the autographically recorded stress-strain curve and the mean elongation computed from ten determinations as percentage increase in length.

4. Distribution of yarns

a. By number

The number of warp yarns per inch of each new and washed fabric was counted in five places within the fabric, of which none was nearer the selvage than one-tenth the width of the fabric and no two included the same yarns. The mean number of filling yarns per inch was determined in the same way. The yarns of all the fabrics were counted with the aid of a thread counter.

Warp shrinkage was computed from the change in number of filling yarns per inch of fabric upon washing and filling shrinkage from change in number of warp yarns.

b. By weight

Four two-inch squares of each new and washed fabric were cut no nearer the selvage than one-tenth the width of the fabric. Each of these squares was conditioned for one week at 65 ± 2 percent relative humidity and $70^{\circ}\pm2^{\circ}$ F., weighed to the nearest milligram, and raveled into constituent yarns. All the warp yarns from a square were weighed together to the nearest milligram; percentage by weight of the filling yarns in the fabric was determined in the same way and means were computed from four determinations.

5. Length of fiber

A warp yarn longer than any of its individual fibers was untwisted to secure a bundle of fibers; ten were measured to one-sixteenth inch with a linear steel scale.

The mean length of fibers from a filling yarn was determined in the same manner.

6. Thickness of fabric

Measurements of thickness of each new fabric were made at different places in it, exclusive of fabric within six inches of selvage, by means of an automatic micrometer which pressed upon a circle of fabric 0.375 inch in diameter with a pressure of six ounces. The mean thickness was computed from teh observations.

7. Twist of yarn

This determination of the new fabrics was made with an Improved United States Testing Company Tester. The yarn to be tested was removed from the fabric for a distance of approximately ten inches and at this point gripped in the right clamp of the tester and clipped 0.5 inch to its right. This yarn was then removed from the fabric for fifteen inches, and with locking bar open placed in the left clamp, pulled under definite tension (for single yarn a load in grams equal to 131 divided by its yarn number in the typp system was applied; for plied yarns the weight of 100 yards) until the index pointer came in line with the starting mark, tightened in the clamp, and clipped at 0.5 inch to its left. The clamps were set two inches apart for the cotton yarns, four inches for the woolen and worsted yarns, and ten inches for the other yarns. The right clamp was rotated until all twist was removed from the yarn as shown by passing a needle from clamp to clamp between its parallel strands. The mean twist per inch of yarn was computed from ten determinations. A yarn was reported of s twist if, when held in vertical position, its spirals conformed in slope to the central portion of the letter s, and of z twist if the spirals slanted as the middle line of z (5).

8. Weight of fabric

Three specimens, four inches long and the entire width of fabric from each new and washed fabric were conditioned for a week at 65±2 percent relative humidity and 70°±2°F. and weighed to the nearest milligram. Each specimen was then laid without tension on a flat horizontal surface and its length parallel to the selvage was measured to 1/32 inch in five different places with an accurately calibrated linear steel scale. The mean length of the specimens was computed from these five measurements and the mean width either similarly determined or, in the case of washed specimens of full width, computed from the width of the new fabric and the number of warp yarns per inch in the new and the washed fabrics. The mean weight was computed as ounces per square yard of the original fabric (6).

9. Yarn number

Four lengths of warp yarn from a new fabric were measured, wrapped on a card, conditioned for one week at

65±2 percent relative humidity and 70°±2° F., removed separately from the card and weighed to the nearest milligram. The weight of the filling yarn was determined in the same way and the mean yarn numbers were computed as thousands of yards per pound.

Data

TABLE XXXIV. ANALYSIS OF SOAP

Determination number		Anhydrous soap: Soap gram	Anhydrous soap: Anhydrous soap gram	Anhydrous soap: Anhydrous soap percentage of soap	Combined alkali: Sodium hydroxide milliliter 0.2365N	Combined alkali: Sodium oxide percentage of soap	Matter volatile at 105°C.: Residue gram	Matter volatile at 105°C.: Loss percentage of soap
1	Silicated	6.0099	4.7538	79.1	74.80	9.12		
2	soap	6.0093	4.7381	78.9	74.30	9.06		
3		6.0158	4.7286	78.6	74.40	9.07		
4		2.0994					2.0223	3.7
5		1.2975					1.2493	3.7
6		1.3920					1.3404	3.7
7		1.4415					1.3900	3.6
Mean				78.9		9.08		3.7
Deviation				0.2		0.02		0.0
1	Soap	5.0063	4.9172	98.2	67.60	9.90		
2		5.0120	4.9090	97.9	67.60	9.89		
3		5.0118	4.9544	98.9	68.20	9.98		
4		2.0163					1.9989	0.9
5		2.0003					1.9855	0.7
6		2.0107					1.9958	0.7
Mean				98.3		9.92		0.8
Deviation				0.4		0.04		0.1

TABLE XXXIV. (Continued)

Determination number	Soap	Sample gram	Acid number of fat acids: Sodium hydroxide milliliter 0.2365N	Acid number of fat acids: Potassium hydroxide milligram per gram of fat acid	Titer °C.	Alkaline silicate as silicon dioxide gram	Alkaline silicate as silicon dioxide percentage of soap	Total silica as silicon dioxide gram	Total silica as silicon dioxide percentage of soap
1	Silicated soap	2.0454	34.38	223.02					
2		2.0200	34.05	223.66					
3		2.1132	35.65	223.84					
4		2.0092	33.72	222.68					
5		2.0213	34.05	223.52					
6		5.9980				0.0781	1.30		
7		5.9988				0.0755	1.26		
8		1.5842						0.0978	6.17
9		1.5567						0.0940	6.04
10		1.5277						0.0923	6.04
11		1.5075						0.0927	6.15
12					35.0				
13					35.0				
14					35.0				
Mean				223.34	35.0		1.28		6.10
Deviation				0.39	0.0		0.02		0.06
1	Soap	2.5134	37.45	197.70					
2		2.1697	32.45	198.45					
3		2.2382	33.40	198.04					
4		2.2159	33.00	197.60					
5					12.8				
6					13.0				
7					12.8				
Mean				197.77	12.8				
Deviation				0.16	0.1				

TABLE XXXIV. (Continued)

Determination	Soap		Alcohol-insoluble matter				Water-insoluble matter	
			Residue		Water extract		Residue	
					Hydrochloric acid	Sodium oxide		
number		gram	gram	percentage of soap	milliliter 0.3324N	percentage of soap	gram	percentage of soap
1	Silicated	5.9980	0.9247	15.42	30.50	5.24	0.3159	5.27
2	soap	5.9988	0.9235	15.39	29.60	5.08	0.3210	5.35
3		5.0399			25.20	5.15		
4		5.0510			24.40	4.98		
Mean				15.41		5.11		5.31
Deviation				0.02		0.08		0.04

TABLE XXXV. ANALYSIS OF SULFATED ALCOHOL

Determination number	Sulfated alcohol	Sulfuric acid-treated ash		Alcohol-insoluble matter		Ether-soluble matter	
	gram	gram	percentage of detergent	gram	percentage of detergent	gram	percentage of detergent
1	1.0292	0.6343	61.63				
2	1.0050	0.6157	61.26				
3	1.0146	0.6245	61.55				
4	5.0372			2.3523	46.70		
5	4.9452			2.3045	46.60		
6	4.7232			2.2171	46.94		
7	3.3611					0.0578	1.72
8	3.9385					0.0702	1.78
Mean			61.48		46.75		1.75
Deviation			0.15		0.13		0.03

TABLE XXXV. (Continued)

Determination number	Sulfated alcohol gram	Barium sulfate gram	Hydrochloric acid milliliter 0.4887N	Sodium hydroxide milliliter 0.2074N	Total sulfur percentage of detergent	Total sulfate sulfur percentage of detergent	Organic sulfate sulfur percentage of detergent
1	2.0646		50.00	130.60			4.12
2	2.0565		50.00	130.30			4.03
3	2.0221	2.2018	50.00	130.10		14.96	4.04
4	2.1087	2.2673	50.00	130.40		14.77	3.97
5	0.3056	0.3768			16.93		
6	0.3028	0.3719			16.88		
7	0.3023	0.3711			16.86		
8	0.3021	0.3647			16.59*		
Mean					16.89	14.87	4.04
Deviation					0.03	0.10	0.04

* Rejected observation

TABLE XXXVI. ANALYSIS OF FABRICS

Fabric	Weight	Thickness	Absorption of light	Ash	Distribution of yarns in fabric			
	ounces per square yard	inch	percentage	percentage of fabric	number warp yarns per inch	number filling yarns per inch	percentage warp yarns by weight	percentage filling yarns by weight
1. Cellulose	3.81	0.0095	20	1.03	125	69	71.3	27.8
2. Regenerated cellulose	2.87	0.0073	19	0.63	100	50	73.3	26.5
3. Cellulose acetate	2.88	0.0067	16	0.13	183	61	60.5	39.2
4. Silk	5.08	0.0097	26	0.28	262	63	41.0	58.9
5. Wild silk	1.45	0.0039	35	0.57	75	65	50.9	46.6
6. Wool	9.72	0.0188	30	0.19	31	31	52.0	48.0

TABLE XXXVI. (Continued)

Fabric	Breaking strength				Elongation at breaking load			
	Conditioned		Wet		Conditioned		Wet	
	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
	pounds per inch	pounds per inch	pounds per inch	pounds per inch	percentage	percentage	percentage	percentage
1. Cellulose	72	31	69	41	20	11	28	14
2. Regenerated cellulose	36	10	18	2	27	31	26	25
3. Cellulose acetate	30	22	17	11	7	7	30	28
4. Silk	43	44	40	46	44	62	51	96
5. Wild silk	23	24	22	25	31	32	41	41
6. Wool	40	34	26	22	53	45	74	63

TABLE XXXVI. (Continued)

Fabric	Yarn number: Warp	Yarn number: Filling	Twist of yarn: Warp	Twist of yarn: Filling	Type of yarn: Warp	Type of yarn: Filling	Length of fiber
	thousand yards per pound	thousand yards per pound	number per inch, direction	number per inch, direction			inch
1. Cellulose	30.58	39.32	ply 11s single 6z	10s	2-ply	single	1.26
2. Regenerated cellulose	29.54	36.15	<1	58s, 55z*	multi-filament	crepe	continuous
3. Cellulose acetate	63.00	31.10	<1	<1	multi-filament	multi-filament	continuous
4. Silk	77.36	17.26	<1	44s, 46z*	multi-filament	crepe	continuous
5. Wild silk	65.74	57.97	<1	<1	multi-filament	multi-filament	continuous
6. Wool	4.05	3.50	11z	11z	woolen	woolen	3.24

* Two s-twisted yarns alternate with two z-twisted yarns

TABLE XXXVIA. THICKNESS OF NEW FABRICS

Determination number	Cellulose inch	Regenerated cellulose inch	Cellulose acetate inch	Silk inch	Wild silk inch	Wool inch
1	0.0097	0.0074	0.0067	0.0094	0.0037	0.0196
2	0.0093	0.0074	0.0067	0.0096	0.0038	0.0193
3	0.0100	0.0076	0.0067	0.0097	0.0041	0.0184
4	0.0096	0.0073	0.0067	0.0097	0.0040	0.0188
5	0.0094	0.0072	0.0066	0.0098	0.0037	0.0184
6	0.0097	0.0071	0.0066	0.0095	0.0038	0.0192
7	0.0094	0.0072	0.0066	0.0099	0.0038	0.0186
8	0.0093	0.0070	0.0067	0.0097	0.0039	0.0185
9	0.0095	0.0072	0.0068	0.0099	0.0039	0.0182
10	0.0093	0.0074	0.0067	0.0093	0.0036	0.0192
Mean	0.0095	0.0073	0.0067	0.0097	0.0039	0.0188
Deviation	0.0002	0.0001	0.0000	0.0002	0.0001	0.0004

TABLE XXXVIB. DISTRIBUTION OF YARNS BY WEIGHT IN NEW FABRICS

Determination number	Fabric		Warp yarn		Filling yarn	
		gram	gram	percentage of fabric	gram	percentage of fabric
1	Cellulose	0.350	0.250	71.4	0.101	28.9
2		0.259	0.184	71.0	0.075	28
3		0.330	0.236	71.5	0.092	28
4		0.268	0.194	72.4x	0.074	28
Mean				71.3		28
Deviation				0.2		0
1	Regenerated cellulose	0.240	0.176	73.3	0.063	26
2		0.228	0.167	73.2	0.060	26
3		0.241	0.176	73.0	0.065	27
4		0.226	0.166	73.5	0.060	27
Mean				73.3		27
Deviation				0.2		1
1	Cellulose acetate	0.245	0.148	60.4	0.096	39
2		0.256	0.156	60.9	0.100	39.1
3		0.224	0.135	60.3	0.088	39
4		0.238	0.144	60.5	0.093	39
Mean				60.5		39
Deviation				0.2		0
1	Silk	0.456	0.188	41.2	0.267	58.6
2		0.468	0.192	41.0	0.276	59.0
3		0.466	0.190	40.8	0.275	59.0
4		0.506	0.212	41.9x	0.290	57.3x
Mean				41.0		58.9
Deviation				0.1		0.2
1	Wild silk	0.102	0.053	52	0.046	45
2		0.108	0.055	51	0.050	46
3		0.120	0.060	50	0.056	47
4		0.122	0.062	51	0.057	47
Mean				51		46
Deviation				0		1
1	Wool	0.830	0.426	51.3	0.400	48.2
2		0.918	0.486	52.9	0.430	46.8
3		0.844	0.438	51.9	0.403	46.6
4		0.914	0.473	51.8	0.442	48.4
Mean				52.0		48.0
Deviation				0.5		0.8

x rejected observation

TABLE XXXVIC. YARN NUMBERS OF NEW FABRICS

Determination number	Fabric	Warp yarn: Length inch	Warp yarn: Weight gram	Warp yarn: Weight typp	Filling yarn: Length inch	Filling yarn: Weight gram	Filling yarn: Weight typp
1	Cellulose	360	0.148	30.7	390	0.123	40.0
2		360	0.148	30.7	390	0.128	38.4
3		360	0.149	30.4	390	0.124	39.6
4		360	0.152	29.8x			
Mean				30.6			39.3
Deviation				0.1			0.6
1	Regenerated cellulose	340	0.145	29.5	350	0.122	36.2
2		340	0.145	29.5	350	0.122	36.2
3		340	0.145	29.5	350	0.122	36.2
4		340	0.145	29.5	350	0.122	36.2
Mean				29.5			36.2
Deviation				0.0			0.0
1	Cellulose acetate	360	0.072	63	385	0.157	30.9
2		360	0.071	64	385	0.157	30.9
3		360	0.072	63	385	0.155	31.3
4		360	0.072	63	385	0.155	31.3
Mean				63			31.1
Deviation				0			0.2
1	Silk	170	0.029	74	480	0.410	14.8x
2		170	0.029	74	480	0.366	16.5
3		170	0.026	82	480	0.343	17.6
4		170	0.027	79	480	0.343	17.6
Mean				77			17.2
Deviation				3			0.5
1	Wild silk	120	0.023	68	340	0.072	60
2		120	0.023	68	340	0.072	60
3		120	0.023	68	340	0.078	55
4		120	0.023	68	340	0.088	49x
Mean				68			58
Deviation				0			2
1	Wool	350	1.108	3.98	335	1.225	3.37x
2		350	1.073	4.11	335	1.205	3.50
3		350	1.096	4.02	335	1.192	3.54
4		350	1.084	4.07	335	1.170	3.61
Mean				4.05			3.55
Deviation				0.05			0.04

x rejected observation

TABLE XXXVID. TWIST OF YARNS IN NEW FABRICS*

Determination number	Cellulose			Regenerated cellulose		Silk		Wool	
	number of ply twists per two inches of warp	number of single twists per two inches of warp	number of single twists per two inches of filling	number of s-twists per ten inches of filling	number of z-twists per ten inches of filling	number of s-twists per ten inches of filling	number of z-twists per ten inches of filling	number of z-twists per four inches of warp	number of z-twists per four inches of filling
1	22	22	21	593	531	462	458	44.7	43.6
2	21	22	18	599	595	435	455	46.7	44.5
3	20	22	21	598	548	468	463	45.8	48.0x
4	21	22	18	546	545	446	413	43.6	46.3
5	20	22	20	593	541	318x	469	36.2x	44.8
6	22	22	19	558	547	436	491	46.4	41.7
7	20	22	19	598	531	463	433	49.2	46.0
8	22	22	18	546	561	438	448	45.0	42.7
9	21	22	18	574	560	452	469	47.3	42.3
10	21	22	17	597	547	448	459	49.7	43.4
Deviation	1	0	1	19	13	10	15	2	1
Mean per inch	11	11	10	58	55	45	46	12	11

x rejected observation

* The yarns of the cellulose-acetate rayon faille taffeta and the wild silk pongee and the warp yarns of the regenerated-cellulose rayon crepe and the silk crepe showed no measurable twist.

TABLE XXXVII. LENGTH OF FIBER IN NEW FABRICS

Determination number	Cellulose inch	Regenerated cellulose inch	Cellulose acetate inch	Silk inch	Wild silk inch	Wool inch
Warp						
1	1.25					2.50
2	1.25					4.00
3	1.13					2.25
4	1.25					2.13
5	1.25					2.13
6	1.38					5.25
7	1.25					2.75
8	1.13					4.00
9	1.38					3.00
10	1.38					2.50
Mean	1.27	continuous	continuous	continuous	continuous	3.05
Deviation	0.07					0.82
Filling						
1	1.25					3.38
2	1.25					3.50
3	1.38					2.50
4	1.13					4.00
5	1.25					3.75
6	1.25					3.75
7	1.25					4.00
8	1.25					2.75
9	1.25					3.75
10	1.25					3.13
Mean	1.25	continuous	continuous	continuous	continuous	3.43
Deviation	0.03					0.41

TABLE XXXVI F. BREAKING STRENGTH AND ELONGATION OF NEW FABRICS

Determination	Conditioned				Wet			
	Warp		Filling		Warp		Filling	
	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
1. Cellulose								
1	68	0.89	30	0.33	70	0.89	41	0.44
2	78	0.44	24	0.33	68	0.78	43	0.44
3	76	0.44	32	0.33	74x	0.78x	41	0.44
4	65	0.67	34	0.44	69	0.89	41	0.33
5	32x	1.00x	28	0.33	68	0.78	43	0.44
6	76	0.67	34	0.33	68	0.89	41	0.44
7	74	0.56	32	0.33	70	0.89	39	0.44
8	70	0.56	30	0.33	70	0.78	43	0.44
9	77	0.56	22x	0.33x	70	0.89	41	0.44
10	68		32	0.33	67		41	0.33
Mean	72	0.60	31	0.34	69	0.85	41	0.42
Deviation	4	0.11	2	0.02	1	0.05	1	0.03
Mean per yarn	0.576		0.449		0.552		0.594	
Percentage		20		11		28		14

x Rejected observation

TABLE XXXVI F. (Continued).

Determination	Conditioned				Wet			
	Warp		Filling		Warp		Filling	
	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
2. Regenerated cellulose								
1	41	0.78	10	0.67	19	0.78	2	0.78
2	39	0.89	10	0.67	20	0.78	2	0.78
3	37	0.78	10	0.67	17	0.78	2	0.78
4	30	0.78	11	0.67	17	0.78	2	0.78
5	36	0.89	10	0.67	20	0.89	2	0.78
6	30	0.78	10	0.56	17	0.78	2	0.78
7			10	0.67	20	0.89	2	0.78
8			10	0.44	19	0.78	2	0.78
9			10		17	0.67	2	0.56
10					17	0.78	2	0.78
Mean	36	0.82	10	0.63	18	0.79	2	0.76
Deviation	4	0.05	0	0.06	1	0.04	0	0.04
Mean per yarn	0.360				0.180		0.040	
Percentage		27		31		26		25

TABLE XXXVI F. (Continued).

Determination:	Conditioned				Wet			
	Warp		Filling		Warp		Filling	
	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
5. Cellulose acetate								
1	30	0.67	22	0.22	17	0.89	12	0.78
2	32	0.22	22	0.22	17	0.89	12	0.78
3	30	0.11	22	0.11	17	0.78	12	0.78
4	28	0.56	22	0.22	17	1.00	12	0.89
5	26	0.67	22	0.22	17	0.89	12	0.89
6	31	0.56	22	0.22	19	0.78	12	0.89
7	31	0.22	22	0.33	15	0.89	12	0.67
8	28	0.56	22	0.22	17	1.00	10	0.89
9	30	0.44	22	0.22	19	0.89	10	0.89
10	32	0.22	22	0.22			10	0.89
Mean	30	0.42	22	0.22	17	0.89	11	0.84
Deviation	1	0.21	0	0.02	1	0.05	1	0.07
Mean per yarn	0.164		0.361		0.093		0.180	
Percentage		7		7		30		28

TABLE XXXVI F. (Continued)

Determination	Conditioned				Wet			
	Warp		Filling		Warp		Filling	
	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
4. Silk								
1	41	1.22	44	1.78	43	1.44	46	3.00
2	41	1.33	46	1.89	42	1.78	46	3.00
3	44	1.22	34x	2.00x	39	1.56	36x	
4	43	1.22	46	1.89	34	1.67	45	2.56
5	41	1.33	41	1.89	42	1.22	46	3.00
6	39	1.22			46	1.33		
7	46	1.67			43	1.56		
8	54x	1.33x			32	1.67		
9	48	1.44			38	1.56		
10	45							
Mean	43	1.33	44	1.86	40	1.53	46	2.89
Deviation	2	0.11	2	0.04	4	0.14	0	0.17
Mean per yarn	0.164		0.698		0.153		0.730	
Percentage		44		62		51		96

TABLE XXXVI F. (Continued).

Determination	Conditioned				Wet			
	Warp		Filling		Warp		Filling	
	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
5. Wild silk								
1	22	1.00	26	1.00	23	1.22	24	1.33
2	22	1.00	24	1.11	22	1.22	24	1.33
3	22	0.89	24	1.00	21	1.33	28	1.22
4	24	0.89	24	0.89	21	1.33	26	1.22
5	24	0.89	24	1.00	21	1.11	26	1.22
6	20	0.89	24	0.78	22	1.44	24	1.22
7	24	0.89	24		23	1.11	24	1.11
8	24		26		19	1.11	26	1.11
9	22		24		24	1.22	19x	1.11x
10					21	1.22	24	1.22
Mean	23	0.92	24	0.96	22	1.23	25	1.22
Deviation	1	0.04	0	0.09	1	0.08	1	0.05
Mean per yarn	0.307		0.369		0.293		0.385	
Percentage		31		32		41		41

TABLE XXXVI F. (Contimued)

Determination:	Conditioned				Wet			
	Warp		Filling		Warp		Filling	
	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
6. Wool								
1	39	1.67	34	1.56	26	2.00	22	2.22
2	39	1.67	33	1.33	28	2.33	22	1.78
3	37	1.33	36	1.33	26	2.22	24	1.89
4	41	1.44	33	1.33	24	2.22	22	1.78
5	39	1.67	32	1.44	26	2.00	20	1.89
6	41	1.67	34	1.22	26	2.33	22	1.78
7	39	1.56	34	1.33	28	2.00	22	1.78
8	39	1.56	32	1.44	26	2.33	22	1.78
9	41	1.56	34	1.22	26	2.33	20	1.89
10	41	1.67	35		28	2.33	20	2.00
Mean	40	1.58	34	1.35	26	2.21	22	1.89
Deviation	1	0.09	1	0.08	1	0.13	1	0.09
Mean per yarn	1.290		1.097		0.839		0.710	
Percentage		53		45		74		63

TABLE XXXVII. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE ACETYL OF CELLULOSE ACETATE

Determination number	Detergent	Washing number	Cellulose acetate gram	Hydrochloric acid milliliter* 0.3324N	Acetyl percentage of fabric
1	none	0	1.7436	30.15	38.61
2			1.8674	26.80	38.62
3			1.3548	40.70	38.55
Mean					38.59
Deviation					0.03
1	silicated soap	10	2.0000	22.70	38.99
2			1.7207	30.40	38.91
3			1.7516	29.30	39.13
4			1.3085	41.40	39.15
Mean					39.06
Deviation					0.10
1		20	1.8778	26.00	39.01
2			1.8078	28.00	38.94
3			1.8020	28.10	38.98
4			2.0309	21.65	39.13
Mean					39.02
Deviation					0.06
1		30	1.6646	31.78	39.05
2			1.9808	23.15	39.04
3			1.7240	30.25	38.96
4			1.6510	32.18	39.01
Mean					39.02
Deviation					0.03
1		40	1.6204	32.82	39.19
2			1.7020	30.45	39.30
3			1.7616	28.95	39.19
Mean					39.23
Deviation					0.05

* 77.20 milliliters 0.3324N hydrochloric acid were required for a blank with 25 milliliters sodium hydroxide.

TABLE XXXVII. (Continued)

Determination number	Detergent	Washing number	Cellulose acetate gram	Hydrochloric acid milliliter 0.3324N	Acetyl percentage of fabric
1	silicated	50	1.7332	29.68	39.21
2	soap		1.6997	30.68	39.16
3			1.7736	28.50	39.29
Mean					39.22
Deviation					0.05
1	soap	10	1.9570	23.55	39.22
2			1.5542	34.70	39.12
3			1.8774	25.80	39.17
Mean					39.17
Deviation					0.03
1		20	1.7756	28.50	39.24
2			1.9171	24.68	39.20
Mean					39.22
Deviation					0.02
1		30	1.9623	23.40	39.23
2			1.8844	25.50	39.25
3			1.9316	24.25	39.22
Mean					39.23
Deviation					0.01
1		40	1.7746	28.50	39.26
2			1.9576	23.48	39.21
3			1.6234	32.58	39.33
Mean					39.27
Deviation					0.04
1		50	1.8826	25.52	39.28
2			1.7700	28.65	39.25
Mean					39.27
Deviation					0.02
1	sulfated	10	1.7883	28.30	39.12
2	alcohol		1.8710	26.10	39.08
Mean					39.10
Deviation					0.02

TABLE XXXVII. (Continued)

Determination number	Detergent	Washing number	Cellulose acetate gram	Hydrochloric acid milliliter 0.3324N	Acetyl percentage of fabric
1	sulfated	20	1.6658	31.52	39.24
2	alcohol		1.9974	22.60	39.11
Mean					39.18
Deviation					0.07
1		30	2.0285	21.80	39.08
2			1.8312	27.13	39.12
Mean					39.10
Deviation					0.02
1		40	2.0060	22.30	39.16
2			1.8823	25.60	39.22
3			2.1488	18.25	39.25
Mean					39.21
Deviation					0.03
1		50	1.8689	26.00	39.20
2			1.8173	27.28	39.30
3			1.8719	26.00	39.13
Mean					39.21
Deviation					0.06

TABLE XXXVIII. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE ASH OF FABRICS

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1. Cellulose					
1	none	0	4.7167	0.0486	1.04
2			4.8222	0.0494	1.02
3			4.7344	0.0472	1.00
4			4.5877	0.0478	1.04
Mean					1.03
Deviation					0.02
1	silicated soap	10	5.1463	0.0139	0.27
2			5.2395	0.0130	0.26
3			5.1653	0.0139	0.27
4			5.2029	0.0144	0.28
Mean					0.27
Deviation					0.01
1		20	5.7649	0.0152	0.26
2			5.8140	0.0144	0.25
3			5.7640	0.0142	0.25
4			5.5048	0.0133	0.24
Mean					0.25
Deviation					0.01
1		30	5.3209	0.0208	0.39
2			4.2130	0.0143	0.34
3			4.4425	0.0189	0.43
4			4.7019	0.0140	0.30
Mean					0.37
Deviation					0.05
1		40	3.0110	0.0071	0.24
2			3.0445	0.0078	0.26
3			3.0679	0.0075	0.24
Mean					0.25
Deviation					0.01
1		50	3.2077	0.0100	0.31
2			3.2605	0.0119	0.36
3			3.2555	0.0107	0.33
Mean					0.33
Deviation					0.02

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	soap	10	3.4650	0.0089	0.23
2			3.3130	0.0085	0.26
3			3.2636	0.0073	0.22
Mean					0.24
Deviation					0.02
1		20	3.1047	0.0066	0.21
2			2.9137	0.0091	0.31
3			2.5996	0.0066	0.25
Mean					0.26
Deviation					0.04
1		30	3.3343	0.0084	0.25
2			3.2507	0.0073	0.22
3			2.7280	0.0057	0.21
Mean					0.23
Deviation					0.02
1		40	3.0627	0.0098	0.32
2			3.0633	0.0092	0.30
3			3.0396	0.0096	0.32
Mean					0.31
Deviation					0.01
1		50	3.1106	0.0106	0.34
2			3.1705	0.0107	0.34
3			3.1466	0.0107	0.34
Mean					0.34
Deviation					0.00
1	sulfated alcohol	10	3.1343	0.0070	0.22
2			3.1332	0.0072	0.23
3			3.1140	0.0070	0.22
Mean					0.22
Deviation					0.00
1		20	3.5159	0.0088	0.25
2			3.4319	0.0078	0.23
3			3.4557	0.0082	0.24
Mean					0.24
Deviation					0.01

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	sulfated	30	3.7533	0.0076	0.20
2	alcohol		3.6969	0.0085	0.23
3			3.6443	0.0091	0.23
Mean					0.22
Deviation					0.01
1		40	4.0080	0.0056	0.14
2			3.7437	0.0066	0.18
3			3.8730	0.0066	0.17
Mean					0.16
Deviation					0.02
1		50	4.5960	0.0098	0.21
2			4.7654	0.0092	0.19
Mean					0.20
Deviation					0.01
2. Regenerated cellulose					
1	none	0	5.5351	0.0350	0.63
2			5.5921	0.0349	0.62
3			5.5625	0.0348	0.63
4			5.4956	0.0343	0.63
Mean					0.63
Deviation					0.00
1	silicated	10	3.7034	0.0105	0.28
2	soap		3.9776	0.0115	0.29
Mean					0.29
Deviation					0.01
1		20	3.2457	0.0142	0.44
2			4.2123	0.0189	0.45
3			4.0327	0.0190	0.47
Mean					0.45
Deviation					0.01
1		30	2.3548	0.0081	0.34
2			2.4827	0.0071	0.29
Mean					0.32
Deviation					0.03

TABLE XXXVIII. (Continued)

Determi- nation number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	silicated	40	3.1706	0.0079	0.25
2	soap		3.1036	0.0114	0.36
Mean					0.31
Deviation					0.06
1		50	3.4236	0.0123	0.36
2			3.4198	0.0112	0.33
Mean					0.35
Deviation					0.02
1	soap	10	2.9390	0.0066	0.22
2			3.1581	0.0049	0.16
Mean					0.19
Deviation					0.03
1		20	2.2799	0.0057	0.25
2			2.4419	0.0050	0.20
Mean					0.23
Deviation					0.03
1		30	2.8501	0.0057	0.20
2			2.7852	0.0077	0.28
3			2.6337	0.0069	0.26
Mean					0.25
Deviation					0.03
1		40	3.4290	0.0082	0.24
2			3.1314	0.0050	0.16
Mean					0.20
Deviation					0.04
1		50	1.7503	0.0043	0.25
2			2.0035	0.0047	0.23
3			2.1548	0.0056	0.26
Mean					0.25
Deviation					0.01
1	sulfated	10	0.8666	0.0021	0.24
2	alcohol		0.9541	0.0023	0.24
Mean					0.24
Deviation					0.00

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	sulfated	20	2.2306	0.0031	0.14
2	alcohol		2.3054	0.0040	0.17
Mean					0.16
Deviation					0.02
1		30	2.6410	0.0022	0.08
2			2.7862	0.0018	0.06
Mean					0.07
Deviation					0.01
1		40	3.0006	0.0039	0.13
2			2.4215	0.0015	0.06
3			3.0320	0.0030	0.10
Mean					0.10
Deviation					0.02
1		50	3.7040	0.0053	0.14
2			4.5860	0.0056	0.12
3			2.6663	0.0024	0.09
Mean					0.12
Deviation					0.02
3. Cellulose acetate					
1	none	0	4.2581	0.0061	0.14
2			3.9273	0.0038	0.10
3			4.5797	0.0058	0.13
4			4.4197	0.0062	0.14
Mean					0.13
Deviation					0.01
1	silicated	10	3.5379	0.0043	0.12
2	soap		3.4170	0.0039	0.11
3			3.2874	0.0036	0.11
4			3.3650	0.0036	0.11
Mean					0.11
Deviation					0.00

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	silicated	20	3.1126	0.0036	0.12
2	soap		3.3231	0.0044	0.13
3			3.0229	0.0032	0.11
Mean					0.12
Deviation					0.01
1		30	3.5863	0.0054	0.15
2			3.5549	0.0048	0.13
3			3.7857	0.0035	0.09
4			3.4740	0.0054	0.16
Mean					0.13
Deviation					0.02
1		40	2.3024	0.0017	0.07
2			2.7345	0.0035	0.13
Mean					0.10
Deviation					0.03
1		50	2.5806	0.0013	0.05
2			2.2354	0.0013	0.06
Mean					0.06
Deviation					0.01
1	soap	10	3.0920	0.0010	0.03
2			3.2770	0.0013	0.04
Mean					0.04
Deviation					0.01
1		20	2.5645	0.0000	0.00
2			3.1804	0.0010	0.03
Mean					0.02
Deviation					0.01
1		30	2.4966	0.0011	0.04
2			2.3060	0.0000	0.00
Mean					0.02
Deviation					0.02
1		40	2.0958	0.0000	0.00
2			2.0263	0.0000	0.00
Mean					0.00
Deviation					0.00

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	soap	50	2.0156	0.0011	0.06
2			3.5614	0.0032	0.09
Mean					0.08
Deviation					0.02
1	sulfated	10	3.1243	0.0038	0.12
2	alcohol		2.7865	0.0031	0.11
Mean					0.12
Deviation					0.01
1		20	3.0209	0.0022	0.07
2			3.2042	0.0021	0.07
Mean					0.07
Deviation					0.00
1		30	2.6570	0.0025	0.10
2			2.9689	0.0032	0.11
Mean					0.11
Deviation					0.01
1		40	3.2073	0.0022	0.07
2			3.1754	0.0026	0.08
Mean					0.08
Deviation					0.01
1		50	3.2067	0.0019	0.06
2			3.0642	0.0017	0.06
Mean					0.06
Deviation					0.00
4. Silk					
1	none	0	5.6021	0.0149	0.27
2			5.0689	0.0135	0.27
3			5.6848	0.0164	0.29
4			5.6006	0.0153	0.27
Mean					0.28
Deviation					0.01

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	silicated	10	3.0795	0.0217	0.70
2	soap		2.9080	0.0210	0.72
3			3.3877	0.0247	0.73
Mean					0.72
Deviation					0.01
1		20	2.9013	0.0180	0.62
2			2.7874	0.0179	0.64
3			3.4267	0.0250	0.73
Mean					0.66
Deviation					0.04
1		30	2.6488	0.0176	0.66
2			2.7144	0.0220	0.81
3			2.3066	0.0202	0.88
Mean					0.78
Deviation					0.08
1		40	2.6058	0.0149	0.57
2			2.5497	0.0156	0.61
Mean					0.59
Deviation					0.02
1		50	2.4599	0.0145	0.59
2			2.8472	0.0160	0.56
3			2.6229	0.0146	0.56
Mean					0.57
Deviation					0.01
1	soap	10	2.6643	0.0133	0.50
2			2.0509	0.0095	0.46
Mean					0.48
Deviation					0.02
1		20	2.8813	0.0106	0.37
2			3.2674	0.0125	0.38
3			2.4285	0.0087	0.36
Mean					0.37
Deviation					0.01

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	soap	30	3.2410	0.0165	0.51
2			3.4953	0.0169	0.48
Mean					0.50
Deviation					0.02
1		40	2.6984	0.0163	0.60
2			2.8867	0.0170	0.59
3			2.8090	0.0170	0.60
Mean					0.60
Deviation					0.00
1		50	2.6865	0.0160	0.60
2			2.7051	0.0161	0.60
3			2.7326	0.0191	0.69
Mean					0.63
Deviation					0.04
1	sulfated alcohol	10	2.6800	0.0131	0.49
2			3.1976	0.0156	0.49
3			3.3027	0.0150	0.45
Mean					0.48
Deviation					0.02
1		20	2.9260	0.0149	0.51
2			2.5087	0.0138	0.55
3			2.4080	0.0127	0.53
Mean					0.53
Deviation					0.01
1		30	2.1277	0.0127	0.60
2			2.4060	0.0141	0.59
3			2.3532	0.0137	0.58
Mean					0.59
Deviation					0.01
1		40	3.0710	0.0191	0.62
2			3.3980	0.0215	0.63
3			3.0676	0.0193	0.63
Mean					0.63
Deviation					0.00

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	sulfated alcohol	50	3.2113	0.0237	0.74
2			3.1550	0.0233	0.74
3			2.6474	0.0210	0.79
Mean					0.76
Deviation					0.02
5. Wild silk					
1	none	0	4.3514	0.0244	0.56
2			4.2472	0.0236	0.56
3			3.6936	0.0220	0.60
4			3.4644	0.0199	0.57
Mean					0.57
Deviation					0.01
1	silicated soap	10	1.2297	0.0146	1.19
2			1.5097	0.0178	1.18
Mean					1.19
Deviation					0.01
1		20	1.5332	0.0190	1.24
2			1.0364	0.0123	1.19
Mean					1.22
Deviation					0.03
1		30	1.4038	0.0192	1.37
2			1.4766	0.0168	1.14
Mean					1.26
Deviation					0.12
1		40	1.4157	0.0199	1.41
2			1.4244	0.0179	1.26
Mean					1.34
Deviation					0.08
1		50	1.3702	0.0168	1.23
2			1.5769	0.0205	1.30
Mean					1.27
Deviation					0.04

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	soap	10	1.1570	0.0107	0.92
2			1.1438	0.0110	0.96
Mean					0.94
Deviation					0.02
1		20	1.1045	0.0107	0.97
2			1.1990	0.0106	0.89
Mean					0.93
Deviation					0.04
1		30	1.2891	0.0104	0.81
2			1.2200	0.0082	0.67
Mean					0.74
Deviation					0.07
1		40	0.9330	0.0078	0.84
2			1.0616	0.0086	0.81
Mean					0.83
Deviation					0.02
1		50	0.8426	0.0078	0.92
2			0.8706	0.0088	1.01
Mean					0.97
Deviation					0.05
1	sulfated	10	1.2055	0.0060	0.50
2	alcohol		0.9534	0.0033	0.35
Mean					0.43
Deviation					0.08
1		20	0.7725	0.0057	0.74
2			1.2618	0.0096	0.76
Mean					0.75
Deviation					0.01
1		30	1.2341	0.0089	0.72
2			1.2472	0.0090	0.72
Mean					0.72
Deviation					0.00

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	sulfated	40	1.1094	0.0091	0.82
2	alcohol		1.0850	0.0079	0.73
Mean					0.78
Deviation					0.05
1		50	1.4432	0.0135	0.94
2			1.3952	0.0135	0.97
Mean					0.96
Deviation					0.02
6. Wool					
1	none	0	4.7265	0.0087	0.18
2			4.4362	0.0081	0.18
3			4.7205	0.0092	0.19
4			4.5026	0.0090	0.20
Mean					0.19
Deviation					0.01
1	silicated	10	4.6288	0.0427	0.92
2	soap		4.6082	0.0431	0.94
3			4.4704	0.0424	0.95
Mean					0.94
Deviation					0.01
1		20	4.6127	0.0416	0.90
2			4.1060	0.0359	0.87
3			4.7330	0.0419	0.89
Mean					0.89
Deviation					0.01
1		30	3.9609	0.0482	1.22
2			3.5283	0.0405	1.15
3			3.9995	0.0443	1.11
Mean					1.16
Deviation					0.04
1		40	3.4065	0.0484	1.42
2			3.8492	0.0516	1.34
3			3.4010	0.0443	1.30
Mean					1.35
Deviation					0.04

TABLE XXXVIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Ash gram	Ash percentage of fabric
1	silicated soap	50	2.9585	0.0210	0.71
2			2.5684	0.0167	0.65
3			2.9290	0.0164	0.56
Mean					0.64
Deviation					0.05
1	soap	10	3.3148	0.0293	0.88
2			2.5658	0.0201	0.78
3			2.9245	0.0303	1.04
4			4.5571	0.0440	0.96
Mean					0.92
Deviation					0.09
1		20	2.7341	0.0258	0.94
2			3.8460	0.0304	0.79
3			4.2478	0.0347	0.82
Mean					0.85
Deviation					0.06
1		30	3.1566	0.0279	0.88
2			3.1271	0.0287	0.92
Mean					0.90
Deviation					0.02
1		40	3.0992	0.0230	0.74
2			3.3338	0.0227	0.68
3			3.1534	0.0238	0.75
Mean					0.72
Deviation					0.03
1		50	3.1049	0.0240	0.77
2			3.1395	0.0228	0.73
3			3.6859	0.0280	0.76
Mean					0.75
Deviation					0.02
1	sulfated alcohol	10	3.3165	0.0128	0.39
2			3.3755	0.0134	0.40
3			4.0319	0.0191	0.47
Mean					0.42
Deviation					0.03

TABLE XXXVIII. (Continued)

Determination :	Detergent :	Washing :	Fabric :	Ash	
number		number	gram	gram	percentage of fabric
1	sulfated	20	2.4940	0.0149	0.60
2	alcohol		3.5391	0.0169	0.48
3			3.0756	0.0163	0.53
Mean					0.54
Deviation					0.04
1		30	2.8923	0.0174	0.60
2			3.4117	0.0231	0.68
3			3.1064	0.0238	0.77
Mean					0.68
Deviation					0.06
1		40	3.4694	0.0108	0.31
2			3.4104	0.0115	0.34
3			3.2665	0.0135	0.41
Mean					0.35
Deviation					0.04
1		50	3.5676	0.0132	0.37
2			2.8620	0.0096	0.34
Mean					0.36
Deviation					0.02

TABLE XXXIX. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE DISTRIBUTION OF YARNS IN FABRICS

Determination	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
1. Cellulose							
1	0	126			69		
2		126			69		
3		126			68		
4		124			69		
5		125			68		
Mean		125			69		
Deviation		1			0		
1	10	128	124	126	80	78	79
2		127	126	126	78	79	78
3		126	126	128	80	78	79
4		126	128	127	78	79	78
5		126	127	126	77	79	79
Mean		127	126	127	79	79	79
Deviation		1	1	1	1	0	0
Warp shrinkage, percentage					14	14	14
Filling shrinkage, percentage		1	1	1			

TABLE XXXIX. (Contimued)

Determi-nation	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
1	20	127	128	126	76	77	78
2		128	127	125	79	79	79
3		128	126	126	77	79	79
4		128	128	128	78	79	80
5		128	126	126	76	79	79
Mean		128	127	126	77	79	79
Deviation		0	1	1	1	0	0
Warp shrinkage, percentage					12	14	14
Filling shrinkage, percentage		2	1	1			
1	30	128	128	127	79	79	78
2		128	126	126	79	79	79
3		128	127	127	80	81	80
4		126	128	128	80	79	79
5		130	126	129	78	81	79
Mean		128	127	127	79	80	79
Deviation		1	1	1	1	1	0
Warp shrinkage, percentage					14	17	14
Filling shrinkage, percentage		2	1	1			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
1	40	130	128	129	79	80	79
2		128	129	128	77	78	79
3		128	128	130	77	78	80
4		129	129	126	79	78	79
5		129	130	128	77	79	78
Mean		129	129	128	78	79	79
Deviation		1	1	1	1	1	0
Warp shrinkage, percentage					13	14	14
Filling shrinkage, percentage		3	3	2			
1	50	128	130	128	79	81	79
2		127	126	128	79	81	80
3		130	126	128	79	79	79
4		128	128	127	80	81	78
5		130	128	128	79	82	79
Mean		129	128	128	79	81	79
Deviation		1	1	0	0	1	0
Warp shrinkage, percentage					14	17	14
Filling shrinkage, percentage		3	2	2			

TABLE XXXIX. (Continued)

Determi-nation	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
2. Regenerated cellulose							
1	0	100			50		
2		101			48		
3		99			51		
4		100			51		
5		100			49		
Mean		100			50		
Deviation		0			1		
1	10	122	118	118	56	56	56
2		120	119	114	53	57	54
3		123	117	118	56	54	54
4		121	116	120	55	53	53
5		120	119	120	53	54	52
Mean		121	118	118	55	55	54
Deviation		1	1	2	1	1	1
Warp shrinkage, percentage					10	10	8
Filling shrinkage, percentage		2	2	2			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
1	20	119	118	115	55	55	54
2		123	117	116	57	55	54
3		120	118	117	56	55	56
4		121	114	116	54	54	54
5		123	115	114	57	54	55
Mean		121	116	116	56	55	55
Deviation		1	2	1	1	0	1
Warp shrinkage, percentage					12	10	10
Filling shrinkage, percentage		2	2	2			
1	30	118	118	116	54	54	53
2		117	117	116	53	53	55
3		117	115	116	54	53	53
4		121	117	117	55	53	54
5		120	116	117	55	54	53
Mean		119	117	116	54	53	54
Deviation		2	1	0	1	0	0
Warp shrinkage, percentage					8	6	8
Filling shrinkage, percentage		2	2	2			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
1	40	114	120	115	54	54	56
2		118	117	113	52	53	54
3		119	119	117	53	54	53
4		120	117	115	54	54	55
5		117	120	114	53	56	54
Mean		118	119	115	53	54	54
Deviation		2	1	1	1	1	1
Warp shrinkage, percentage					6	8	8
Filling shrinkage, percentage		2	2	2			
1	50	116	123	116	54	54	53
2		115	120	117	54	55	54
3		117	120	117	54	54	53
4		118	121	116	53	53	55
5		118	122	117	53	54	54
Mean		117	121	117	54	54	54
Deviation		1	1	0	0	0	1
Warp shrinkage, percentage					8	8	8
Filling shrinkage, percentage		2	2	2			

TABLE XXXIX. (Continued)

Determination	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
3. Cellulose acetate							
1	0	184			61		
2		182			62		
3		186			61		
4		180			61		
5		182			61		
Mean		183			61		
Deviation		2			0		
1	10	188	198	194	68	67	65
2		192	192	198	66	68	65
3		190	190	200	65	69	66
4		191	200	202	67	68	65
5		190	192	196	66	67	65
Mean		190	194	198	66	68	65
Deviation		1	4	2	1	1	0
Warp shrinkage, percentage					8	11	7
Filling shrinkage, percentage		4	6	8			

TABLE XXXIX. (Continued)

Determination	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
1	20	198	191	195	67	69	70
2		196	192	196	67	70	68
3		194	194	196	66	70	67
4		194	192	198	67	70	71
5		192	192	194	68	69	69
Mean		195	192	196	67	70	69
Deviation		2	1	1	0	0	1
Warp shrinkage, percentage					10	15	13
Filling shrinkage, percentage		7	5	7			
1	30	196	192	190	67	73	72
2		194	192	188	68	72	70
3		204	192	200	68	72	72
4		196	192	192	68	74	71
5		198	192	192	68	73	72
Mean		198	192	192	68	73	71
Deviation		3	0	3	0	1	1
Warp shrinkage, percentage					11	20	16
Filling shrinkage, percentage		7	5	5			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
1	40	192	192	191	70	73	72
2		190	192	192	70	75	70
3		200	192	193	71	74	70
4		198	192	192	69	73	72
5		200	192	192	70	75	73
Mean		196	192	192	70	74	71
Deviation		4	0	0	0	1	1
Warp shrinkage, percentage					15	21	16
Filling shrinkage, percentage		7	5	5			
1	50	192	192	192	71	75	73
2		192	193	192	70	74	73
3		192	192	200	72	74	71
4		192	192	192	73	74	73
5		192	192	192	70	75	74
Mean		192	192	193	71	74	73
Deviation		0	0	2	1	0	1
Warp shrinkage, percentage					16	21	20
Filling shrinkage, percentage		5	5	5			

TABLE XXXIX. (Continued)

Determination	Washing	Warp yarn: Silicated soap	Warp yarn: Soap	Warp yarn: Sulfated alcohol	Filling yarn: Silicated soap	Filling yarn: Soap	Filling yarn: Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
4. Silk							
1	0	262			62		
2		256			63		
3		263			62		
4		264			64		
5		264			64		
Mean		262			63		
Deviation		2			1		
1	10	240	240	240	61	60	62
2		240	240	240	60	63	62
3		240	240	240	64	62	60
4		240	240	241	61	63	61
5		240	240	239	64	61	60
Mean		240	240	240	62	62	61
Deviation		0	0	0	2	1	1
Warp shrinkage, percentage					-2	-2	-3
Filling shrinkage, percentage		8	8	8			

TABLE XXXIX. (Continued)

Determination	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
1	20	240	240	240	60	64	65
2		240	240	240	63	62	62
3		240	240	238	60	62	65
4		240	240	240	60	62	64
5		240	240	240	63	59	63
Mean		240	240	240	61	62	64
Deviation		0	0	0	1	1	1
Warp shrinkage, percentage					-3	-2	-2
Filling shrinkage, percentage		8	8	8			
1	30	240	240	240	60	57	60
2		240	240	240	62	60	58
3		240	240	240	63	60	61
4		240	240	240	62	58	61
5		240	240	240	65	61	60
Mean		240	240	240	62	59	60
Deviation		0	0	0	1	1	1
Warp shrinkage, percentage					-2	-6	-5
Filling shrinkage, percentage		8	8	8			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
1	40	240	240	240	61	62	61
2		240	240	240	59	64	61
3		240	240	240	60	61	61
4		240	240	240	59	61	61
5		240	240	240	59	58	62
Mean		240	240	240	60	61	61
Deviation		0	0	0	1	1	0
Warp shrinkage, percentage					-5	-3	-3
Filling shrinkage, percentage		8	8	8			
1	50	240	240	240	62	60	61
2		240	240	240	60	60	59
3		240	240	240	61	60	59
4		240	240	240	62	61	62
5		240	240	240	58	61	60
Mean		240	240	240	61	60	60
Deviation		0	0	0	1	0	1
Warp shrinkage, percentage					-3	-5	-5
Filling shrinkage, percentage		8	8	8			

TABLE XXXIX. (Continued)

Determination	Washing	Warp yarn: Silicated soap	Warp yarn: Soap	Warp yarn: Sulfated alcohol	Filling yarn: Silicated soap	Filling yarn: Soap	Filling yarn: Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
5. Wild silk							
1	0	75			65		
2		76			65		
3		75			66		
4		75			65		
5		75			65		
Mean		75			65		
Deviation		0			0		
1	10	78	77	78	68	67	67
2		78	77	77	69	68	69
3		78	77	78	68	68	69
4		77	77	78	69	69	68
5		77	78	77	68	70	69
Mean		78	77	78	68	69	68
Deviation		0	0	0	0	0	1
Warp shrinkage, percentage					5	6	5
Filling shrinkage, percentage		4	3	4			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
1	20	78	79	78	72	69	70
2		78	79	77	72	70	70
3		77	79	78	68	69	70
4		77	78	78	65	67	71
5		77	78	79	71	69	71
Mean		77	79	78	70	69	70
Deviation		0	0	0	2	1	0
Warp shrinkage, percentage					8	6	8
Filling shrinkage, percentage		3	5	4			
1	30	77	78	77	69	66	69
2		77	78	77	68	69	68
3		77	77	77	69	68	68
4		78	78	76	70	68	69
5		79	81	80	69	68	69
Mean		78	78	78	69	68	69
Deviation		1	1	1	0	1	0
Warp shrinkage, percentage					6	5	6
Filling shrinkage, percentage		4	4	4			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
1	40	77	78	78	72	71	69
2		79	79	78	67	74	70
3		78	79	79	68	70	69
4		79	78	78	71	68	71
5		78	78	79	69	73	70
Mean		78	78	78	69	71	70
Deviation		1	0	0	2	2	1
Warp shrinkage, percentage					6	9	8
Filling shrinkage, percentage		4	4	4			
1	50	77	79	78	68	65	70
2		77	79	76	68	65	67
3		77	80	78	68	68	70
4		77	78	79	69	68	69
5		78	80	78	69	66	69
Mean		77	79	78	68	66	69
Deviation		0	1	1	0	1	1
Warp shrinkage, percentage					5	2	6
Filling shrinkage, percentage		3	5	4			

TABLE XXXIX. (Continued)

Determination number	Washing number	Warp yarn: Silicated soap, number per inch	Warp yarn: Soap, number per inch	Warp yarn: Sulfated alcohol, number per inch	Filling yarn: Silicated soap, number per inch	Filling yarn: Soap, number per inch	Filling yarn: Sulfated alcohol, number per inch
6. Wool							
1	0	31			31		
2		32			32		
3		31			30		
4		32			30		
5		31			30		
Mean		31			31		
Deviation		0			1		
1	10	33	30	32	29	29	30
2		32	31	30	29	29	30
3		32	29	32	28	29	30
4		32	31	31	29	29	30
5		32	31	31	29	28	29
Mean		32	30	31	29	28	30
Deviation		0	1	1	0	1	0
Warp shrinkage, percentage					-6	-10	-3
Filling shrinkage, percentage		3	-3	0			

TABLE XXXIX. (Continued)

Determination	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
1	20	33	33	32	29	31	29
2		33	33	32	29	29	29
3		32	33	33	28	29	27
4		31	31	32	29	28	30
5		33	33	32	28	28	30
Mean		32	33	32	29	29	29
Deviation		1	0	0	0	1	1
Warp shrinkage, percentage					-6	-6	-6
Filling shrinkage, percentage		3	6	3			
1	30	34	35	31	29	30	30
2		35	35	31	29	28	29
3		34	34	31	29	28	29
4		34	34	30	29	28	28
5		33	35	30	29	28	29
Mean		34	35	31	29	28	29
Deviation		0	0	0	0	0	0
Warp shrinkage, percentage					-6	-10	-6
Filling shrinkage, percentage		10	13	0			

TABLE XXXIX. (Continued)

Determination	Washing	Warp yarn			Filling yarn		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
number	number	number per inch	number per inch	number per inch	number per inch	number per inch	number per inch
1	40	33	35	34	29	29	30
2		32	35	34	30	29	29
3		34	35	34	29	29	30
4		35	37	35	30	30	29
5		35	36	35	29	28	29
Mean		34	36	34	29	29	29
Deviation		1	1	0	0	0	0
Warp shrinkage, percentage					-6	-6	-6
Filling shrinkage, percentage		10	16	10			
1	50	37	37	34	30	29	31
2		37	36	35	30	30	30
3		37	37	35	30	29	30
4		37	36	34	31	29	29
5		37	36	35	31	29	29
Mean		37	36	35	30	29	30
Deviation		0	0	0	0	0	1
Warp shrinkage, percentage					-3	-6	-3
Filling shrinkage, percentage		19	16	13			

TABLE XL. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE NITROGEN OF SILK, WILD SILK, AND WOOL

Determination	Detergent	Washing	Fabric	Hydrochloric acid		Sodium hydroxide		Nitrogen
number		number	gram	milliliter	normality	milliliter	normality	percentage of fabric
4. Silk								
1	none	0	2.1810	150.30	0.3320	100.00	0.2075	18.72
2			2.3667	151.30		90.00		18.68
Mean								18.70
Deviation								0.02
1	silicated soap	10	2.9728	150.30	0.3163	40.00		18.49
2			2.9545	150.07		42.00		18.37
3			2.7982	151.00		53.00		18.40
Mean								18.42
Deviation								0.05
1		20	2.6268	150.65		62.00		18.55
2			2.6597	150.90		60.00		18.58
Mean								18.57
Deviation								0.02
1		30	2.5940	150.75		65.00		18.47
2			2.7827	152.40		55.00		18.51
Mean								18.49
Deviation								0.02

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	silicated	40	2.5611	150.58	0.3163	66.00	0.2075	18.56
2	soap		2.8540	152.30		50.00		18.55
Mean								18.56
Deviation								0.01
1		50	2.4891	150.50		71.00		18.49
2			2.1010	151.00		97.00		18.42
Mean								18.46
Deviation								0.04
1	soap	10	2.8164	151.40		50.00		18.66
2			3.0830	150.08		32.00		18.55
3			2.6523	150.72		60.00		18.60
Mean								18.60
Deviation								0.04
1		20	2.5182	150.30		69.00		18.48
2			2.6393	151.38		64.00		18.36
Mean								18.42
Deviation								0.06
1		30	2.0029	150.70		102.00		18.53
2			2.6500	152.00		62.00		18.61
Mean								18.57
Deviation								0.04

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	soap	40	2.0164	150.60	0.3163	101.00	0.2075	18.53
2			2.1040	150.60		95.00		18.59
3			1.8088	150.92		115.00		18.49
Mean								18.54
Deviation								0.04
1		50	2.2700	152.35		88.00		18.46
2			2.0680	151.20		100.00		18.34
Mean								18.40
Deviation								0.06
1	sulfated alcohol	10	3.1052	154.10		38.00		18.43
2			2.9980	150.04		38.00		18.49
3			3.3316	151.12		18.00		18.53
Mean								18.48
Deviation								0.04
1		20	3.0078	153.30		45.00		18.23
2			3.6454	151.12		12.00		18.32
Mean								18.28
Deviation								0.05
1		30	2.5954	152.05		68.00		18.34
2			3.4846	153.70		15.00		18.30
Mean								18.32
Deviation								0.02

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	sulfated	40	2.7368	151.22	0.3163	58.00	0.2075	18.32
2	alcohol		2.6354	150.82		64.00		18.30
3			2.5707	150.95		69.00		18.21
Mean								18.28
Deviation								0.04
1		50	3.0508	150.50		38.00		18.24
2			2.9471	151.35		56.00		18.16
Mean								18.20
Deviation								0.04
5. Wild silk								
1	none	0	3.9419	150.00	0.2986	12.64	0.2127	14.96
2			3.8704			13.38		15.18
3			3.9647			4.30		15.50
4			3.5225			29.90		15.28
Mean								15.13
Deviation								0.19
1	silicated	10	1.1713	100.00	0.3166	78.25		17.96
2	soap		1.1353			80.05		18.06
3			1.1676			78.00		18.08
Mean								18.03
Deviation								0.05

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium Hydroxide milliliter	Sodium Hydroxide normality	Nitrogen percentage of fabric
1	silicated	20	0.8626	100.00	0.3166	96.80	0.2127	17.98
2	soap		0.8122			100.00		17.92
Mean								17.95
Deviation								0.03
1		30	0.8574			96.98		18.02
2			0.9195			93.42		17.96
Mean								17.99
Deviation								0.03
1		40	0.9516			91.30		18.02
2			0.9884			88.85		18.09
Mean								18.06
Deviation								0.04
1		50	0.9281		0.2986	92.40		18.12
2			1.0031			88.15		18.03
3			0.9294			92.90		17.94
Mean								18.03
Deviation								0.06
1	soap	10	0.9517	100.40	0.3320	100.00	0.2075	18.52
2			0.9363	102.88		105.00		18.50
Mean								18.51
Deviation								0.01

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	soap	20	1.0732	105.25	0.3320	100.00	0.2075	18.53
2			0.9246	102.45		105.00		18.52
Mean								18.53
Deviation								0.01
1		30	0.9238	102.35		105.00		18.50
2			1.0520	104.40		100.00		18.52
3			1.1810	103.05		90.00		18.43
Mean								18.48
Deviation								0.04
1		40	0.9867	101.30		100.00		18.29
2			1.0459	103.65		100.00		18.30
Mean								18.30
Deviation								0.01
1		50	1.0527	104.45		100.00		18.53
2			0.9584	100.55		100.00		18.46
Mean								18.50
Deviation								0.04
1	sulfated	10	1.2250	103.50		90.00		17.92
2	alcohol		1.2421	110.22		100.00		17.87
3			1.2206	110.18		100.00		18.17
Mean								17.99
Deviation								0.12

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	sulfated	20	0.8714	102.60	0.3320	110.00	0.2075	18.07
2	alcohol		0.9082	104.10		110.00		18.10
3			0.5389	100.45		127.00		18.19
Mean								18.12
Deviation								0.04
1		30	0.7711	102.10		115.00		18.23
2			0.9038	101.30		105.00		18.36
3			0.9060	101.25		105.00		18.29
Mean								18.29
Deviation								0.04
1		40	0.7901	102.70		115.00		18.14
2			0.8883	103.32		110.00		18.10
3			0.8417	101.30		110.00		17.98
Mean								18.07
Deviation								0.06
1		50	0.8186	103.72		115.00		18.09
2			0.8518	101.98		110.00		18.13
3			0.8901	103.40		110.00		18.10
Mean								18.11
Deviation								0.02

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
6. Wool								
1	none	0	2.9863	125.00	0.2986	9.24	0.2127	16.59
2			2.8624	125.00		16.45		16.55
3			3.3330	152.90	0.3320	55.00	0.2075	16.54
4			2.9399	150.90		74.60		16.49
Mean								16.54
Deviation								0.03
1	silicated	10	3.3749	157.00	0.3163	50.00		16.31
2	soap		3.1667	151.20		52.00		16.38
Mean								16.35
Deviation								0.04
1		20	3.7608	172.00		50.00		16.40
2			4.1022	200.42		73.00		16.47
3			3.8741	201.90		90.00		16.34
Mean								16.40
Deviation								0.04
1		30	3.2900	155.70		50.00		16.55
2			3.4184	160.20		50.00		16.51
Mean								16.53
Deviation								0.02

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	silicated	40	3.6534	167.50	0.3163	50.00	0.2075	16.34
2	soap		3.3470	156.28		50.00		16.35
3			3.4940	161.40		50.00		16.31
Mean								16.33
Deviation								0.02
1		50	3.6960	169.05		50.00		16.34
2			3.1530	151.10		54.00		16.26
3			3.5483	163.50		50.00		16.32
Mean								16.31
Deviation								0.03
1	soap	10	3.0181	151.05		60.00		16.40
2			2.9050	151.15		67.00		16.35
3			2.8307	150.75		70.00		16.41
Mean								16.39
Deviation								0.02
1		20	3.2325	152.95		50.00		16.47
2			3.6683	168.90		50.00		16.44
Mean								16.46
Deviation								0.02
1		30	3.5583	165.10		50.00		16.47
3			3.3321	155.95		50.00		16.38
3			3.3604	156.75		50.00		16.34
Mean								16.40
Deviation								0.05

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	soap	40	4.8324	212.45	0.3163	50.00	0.2075	16.49
2			4.5786	202.80		50.00		16.45
Mean								16.47
Deviation								0.02
1		50	4.3652	200.40		60.00		16.35
2			3.4770	160.92		50.00		16.33
Mean								16.34
Deviation								0.01
1	sulfated alcohol	10	3.8889	176.90		50.00		16.42
2			3.4810	161.85		50.00		16.43
3			3.0040	153.25		65.00		16.31
Mean								16.39
Deviation								0.05
1		20	3.6082	165.48		50.00		16.30
2			3.3976	157.40		50.00		16.25
3			3.2843	152.60		50.00		16.16
Mean								16.24
Deviation								0.05
1		30	3.1436	151.80		55.00		16.31
2			4.0931	200.65		92.00		16.26
Mean								16.29
Deviation								0.03

TABLE XL. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Hydrochloric acid milliliter	Hydrochloric acid normality	Sodium hydroxide milliliter	Sodium hydroxide normality	Nitrogen percentage of fabric
1	sulfated alcohol	40	3.8195	201.03	0.3163	111.00	0.2075	16.03
2			3.5582	161.10		50.00		15.98
3			3.4783	159.18		50.00		16.10
Mean								16.04
Deviation								0.04
1		50	3.1960	150.82		57.00		15.73
2			3.1086	151.00		60.00		15.91
Mean								15.82
Deviation								0.09

TABLE XLI. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE PERCENTAGE OF LIGHT ABSORBED BY FABRICS

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1. Cellulose				
1	0	20		
2		20		
3		20		
4		19		
5		21		
Mean		20		
Deviation		0		
1	10	17	18	20
2		17	19	20
3		17	18	20
4		17	18	20
5		17	18	20
Mean		17	18	20
Deviation		0	0	0
1	20	17	18	21
2		17	18	20
3		17	18	20
4		17	18	20
Mean		17	18	20
Deviation		0	0	0
1	30	16	17	20
2		16	18	21
3		16	18	21
4		16	18	21
5		17	18	20
Mean		16	18	21
Deviation		0	0	0
1	40	17	18	21
2		16	18	21
3		16	18	21
4		17	18	21
5		16	18	21
Mean		16	18	21
Deviation		0	0	0

TABLE XLI. (Continued)

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1	50	16	18	22
2		16	18	22
3		16	18	22
4		16	18	22
5		16	18	22
Mean		16	18	22
Deviation		0	0	0

2. Regenerated cellulose

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1	0	20		
2		21		
3		20		
4		20		
5		20		
Mean		20		
Deviation		0		
1	10	19	21	25
2		20	19	26
3		20	19	27
4		17	20	28
5		18	20	27
Mean		19	20	27
Deviation		0	0	0
1	20	19	19	22
2		20	20	20
3		19	20	20
4		19	21	20
5		20	20	20
Mean		19	20	20
Deviation		0	0	0
1	30	16	19	21
2		16	19	20
3		16	17	21
4		16	19	20
5		17	19	19
Mean		16	19	20
Deviation		0	0	1

TABLE XLI. (Continued)

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1	40	16	22	21
2		15	22	20
3		15	23	20
4		15	23	20
5		14	22	21
Mean		15	22	20
Deviation		0	0	0
1	50	16	25	
2		16	24	
3		16	24	
4		15	24	
5		16	23	
Mean		16	24	
Deviation		0	0	
3. Cellulose acetate				
1	0	16		
2		17		
3		15		
4		15		
5		15		
Mean		16		
Deviation		1		
1	10	12	13	12
2		12	13	13
3		12	13	13
4		12	13	13
5		12	13	12
Mean		12	13	13
Deviation		0	0	0
1	20		13	12
2			13	12
3			13	13
4			13	12
5			13	12
Mean			13	12
Deviation			0	0

TABLE XLI. (Continued)

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1	30		12	13
2			12	13
3			12	13
4			13	13
5			12	13
Mean			12	13
Deviation			0	0
1	40	12	13	13
2		13	12	12
3		13	12	12
4		12	13	11
5		12	13	12
Mean		12	13	12
Deviation		0	0	0
1	50	12	14	12
2		12	13	11
3		11	12	12
4		12	12	11
5		12	12	12
Mean		12	13	12
Deviation		0	1	0
4. Silk				
1	0	26		
2		26		
3		26		
4		25		
5		26		
Mean		26		
Deviation		0		
1	10	24	25	26
2		24	24	27
3		24	24	26
4		24	24	28
5		24	25	27
Mean		24	24	27
Deviation		0	0	1

TABLE XLI. (Continued)

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1	20	21	24	29
2		21	25	29
3		22	25	31
4		22	25	30
5		22	24	30
Mean		22	25	30
Deviation		0	0	1
1	30	22	25	35
2		23	25	35
3		23	26	35
4		23	26	36
5		22	25	35
Mean		23	25	35
Deviation		0	0	0
1	40	23	24	34
2		23	25	34
3		23	24	34
4		22	24	33
5		22	25	34
Mean		23	24	34
Deviation		0	0	0
1	50	26	26	41
2		26	27	39
3		27	27	40
4		26	28	39
5		26	26	40
Mean		26	27	40
Deviation		0	1	1
5. Wild silk				
1	0	34		
2		35		
3		35		
4		35		
5		35		
Mean		35		
Deviation		0		

TABLE XLI. (Continued)

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1	10	51	52	49
2		51	51	50
3		50	52	49
4		50	52	50
5		50	51	48
Mean		50	52	49
Deviation		0	0	1
1	20	47	51	55
2		45	51	54
3		46	51	54
4		47	52	54
5		46	51	54
Mean		46	51	54
Deviation		1	0	0
1	30	47	52	54
2		49	48	56
3		47	50	55
4		47	51	54
5		47	49	55
Mean		47	50	55
Deviation		0	1	1
1	40		50	56
2			50	57
3			49	55
4			49	55
5			52	56
Mean			50	56
Deviation			1	1
1	50		49	56
2			49	56
3			48	56
4			47	56
5			48	56
Mean			48	56
Deviation			1	0

TABLE XLI. (Continued)

Determination	Washing	Silicated soap	Soap	Sulfated alcohol
6. Wool				
1	0	30		
2		31		
3		30		
4		30		
5		31		
Mean		30		
Deviation		0		
1	10	30	30	32
2		27	31	33
3		28	31	30
4		27	30	31
5		28	30	31
Mean		28	30	31
Deviation		1	0	1
1	20	30		37
2		28		38
3		28		37
4		28		37
5		28		37
Mean		28		37
Deviation		0		0
1	30	28	30	37
2		28	30	37
3		29	31	38
4		28	31	37
5		30	31	37
Mean		29	31	37
Deviation		1	0	0
1	40	29	32	38
2		30	31	38
3		32	31	38
4		31	31	38
5		32	32	38
Mean		31	31	38
Deviation		1	0	0

TABLE XLI. (Continued)

Determination number	Washing number	Silicated soap	Soap	Sulfated alcohol
1	50	31	31	44
2		33	31	45
3		32	32	45
4		31	31	45
5		32	32	44
Mean		32	31	45
Deviation		1	0	0

TABLE XLII. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE WET WARP STRENGTH AND ELONGATION OF FABRICS

Determination	Washing	Silicated soap		Soap		Sulfated alcohol	
		Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
1. Cellulose							
1	10	52	1.22	46	0.89	52	0.89
2		54	1.00	52	0.78	57	0.89
3		56	1.00	50	0.89	48	0.78
4		56	1.22	52	0.89	50	0.78
5		52	1.00	48	0.89	44x *	0.78x
6		57	1.11	44	0.89	52	1.00
7		48	0.89	46	0.89	50	0.89
8		66x	1.11x	44	0.89	48	1.00
9		48	0.89	50	1.11	50	0.89
10		54	0.89	54	1.33		
Mean		53	1.02	49	0.95	51	0.89
Deviation		3	0.10	3	0.11	2	0.06
Mean per yarn		0.417		0.389		0.402	
Percentage			34		32		30

* Rejected observation

TABLE XLII. (Contimued)

Determination	Washing	Silicated soap		Soap		Sulfated alcohol	
		Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
1	20	52	1.11	52	1.11	37	0.89
2		41	0.78	50	1.00	54	1.00
3		50	0.78	48	1.00	50	1.00
4		37x	0.78x	48	0.89	48	1.00
5		41	0.78	44	0.89	57	1.11
6		50	0.89	44	0.89	57	1.11
7		56	1.00	60	1.00	52	0.78
8		54	1.00	64x	1.00x	46	0.89
9		50	0.89	48	0.89		
10				50	0.89		
Mean		49	0.90	49	0.95	51	1.00
Deviation		4	0.10	3	0.07	4	0.10
Mean per yarn		0.383		0.386		0.405	
Percentage			30		32		33
1	30	50	1.00	45	0.89	64x	0.89x
2		48	1.00	48	0.78	54	1.00
3		50	1.00	43	0.89	54	1.22
4		52	1.11	43	0.78	59	1.11
5		50	0.89	50	1.22	48	
6		52	1.00	46	0.89	50	
7		47	1.00	48	0.89	48	
8		48	1.11	44	0.78	54	
9		56x	0.89x	46	0.89	52	
Mean		50	1.01	46	1.00	52	1.11
Deviation		1	0.05	2	0.16	3	0.08
Mean per yarn		0.391		0.362		0.409	
Percentage			34		33		37

TABLE XLII. (Continued)

Determination	Washing	Silicated soap		Soap		Sulfated alcohol	
		Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
1	40	50	1.00	44	1.11	54	0.78
2		44	0.67	45	0.78	46	1.00
3		52	0.89	39	0.89	46	0.78
4		56	1.00	43	0.78	48	0.78
5		52	1.11	45	0.89	52	1.11
6		54	1.00	41	0.89	50	0.78
7		48	0.89	44	0.89	56	0.78
8		54	1.22	44	0.89	54	1.00
9		54	1.22	44	1.22	54	1.11
10		56	1.11	46		46	0.78
Mean		52	1.01	44	0.93	51	0.89
Deviation		3	0.12	1	0.11	3	0.12
Mean per yarn		0.403		0.341		0.398	
Percentage			34		31		30
1	50	46	0.78	41	0.78	50	0.78
2		44	0.89	32x	0.78x	48	0.89
3		50	0.89	43	0.78	50	0.89
4		46	0.89	43	0.78	53	0.89
5		46	1.22	43	0.89	66x	1.11x
6		44	0.89	44	0.89	52	1.00
7		50	0.89	41	0.89	56	1.11
8		46	0.89	44	0.78	52	0.89
9		44	1.11	48		52	0.89
10		44	1.00			50	0.89
Mean		46	0.93	43	0.83	51	0.91
Deviation		2	0.09	2	0.05	2	0.06
Mean per yarn		0.357		0.336		0.398	
Percentage			31		28		30

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength, pounds per inch	Silicated soap: Elongation, inch	Soap: Breaking strength, pounds per inch	Soap: Elongation, inch	Sulfated alcohol: Breaking strength, pounds per inch	Sulfated alcohol: Elongation, inch
2. Regenerated cellulose							
1	10	19	0.78	19	0.67	19	0.78
2		17	0.67	19	0.67	17	0.78
3		19	0.78	19	0.78	21	0.78
4		17	0.78	19	0.78	19	0.78
5		21	0.78	17	0.78	21	0.78
6		20	0.56	19	0.67	22	0.89
7		19	0.78	17	0.78	20	0.89
8		17	0.67	17	0.78	19	0.89
9		20	0.78			20	0.78
Mean		19	0.73	18	0.72	20	0.82
Deviation		1	0.07	1	0.06	1	0.05
Mean per yarn		0.157		0.153		0.169	
Percentage			24		24		27

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength pounds per inch	Silicated soap: Elongation inch	Soap: Breaking strength pounds per inch	Soap: Elongation inch	Sulfated alcohol: Breaking strength pounds per inch	Sulfated alcohol: Elongation inch
1	20	20	0.78	15	0.56	19	0.67
2		21	0.89	17	0.78	20	0.78
3		20	0.78	19	0.67	16	0.56
4		19	0.78	17	0.78	20	0.89
5		19	0.78	17	0.78	19	0.78
6		22	0.78	19	0.78	13x	0.67x
7		21	0.78	14	0.44	21	0.78
8		17	0.67	19	0.67		
9		17	0.67	17	0.44		
10				19	0.67		
Mean		20	0.77	17	0.66	19	0.74
Deviation		1	0.04	1	0.11	1	0.12
Mean per yarn		0.165		0.147		0.164	
Percentage			26		22		25
1	30	19	0.67	19	0.78	19	0.67
2		20	0.78	17	0.89	16	0.56
3		19	0.78	17	0.78	19	0.56
4		17	0.78	17	0.67	17	0.67
5		16	0.78	14	0.78	17	0.56
6		19	0.78	19	0.67	16	0.67
7		21	0.78	19	0.78		
8		19	0.78	19	0.89		
9		19	0.67	16	0.56		
Mean		19	0.76	17	0.76	17	0.56
Deviation		1	0.04	1	0.08	1	0.06
Mean per yarn		0.160		0.145		0.147	
Percentage			25		25		19

TABLE XLII. (Continued)

Determination: number	Washing: number	Silicated soap: Breaking strength: pounds per inch	Silicated soap: Elongation: inch	Soap: Breaking strength: pounds per inch	Soap: Elongation: inch	Sulfated alcohol: Breaking strength: pounds per inch	Sulfated alcohol: Elongation: inch
1	40	19	0.78	19	0.78	17	0.67
2		19	0.67	21	0.78	17	0.67
3		17	0.56	17	0.78	15	0.67
4		17	0.78	17	0.67	15	0.78
5		17	0.67	19	0.78	19	0.67
6		17	0.78	16	0.78	16	0.78
7		17	0.67			17	0.67
8		19	0.78			19	
Mean		18	0.71	18	0.76	17	0.71
Deviation		1	0.07	2	0.03	1	0.05
Mean per yarn		0.153		0.151		0.145	
Percentage			24		25		24
1	50	19	0.78	17	0.78	17	0.67
2		17	0.56	19	0.78	13	0.67
3		19	0.78	20	0.78	13	0.56
4		16	0.78	16	0.78	17	0.67
5		19	0.78	17	0.56	17	0.56
6		19	0.78	17	0.56	16	0.44
7		17	0.56	16	0.67	15	0.56
8		15	0.67	17	0.78	17	0.67
9		19	0.89	17	0.78		
Mean		18	0.73	17	0.72	16	0.60
Deviation		1	0.09	1	0.08	1	0.07
Mean per yarn		0.154		0.140		0.137	
Percentage			24		24		20

TABLE XLII. (Continued)

Determination	Washing	Silicated soap		Soap		Sulfated alcohol	
		Breaking strength	Elongation	Breaking strength	Elongation	Breaking strength	Elongation
number	number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
3. Cellulose acetate							
1	10	17	1.00	17	1.11	17	1.00
2		17	0.89	16	1.00	17	1.11
3		17	1.11	17	1.00	16	0.89
4		17	1.11	16	1.11	17	1.11
5		17	1.11	17	1.11	19	1.11
6		19	1.11	17	1.00	16	0.78
7		19	1.22	19	1.11	19	1.00
8		17	1.11	17	0.89	17	1.11
9		17	1.11	17	1.11	19	1.11
10		17	1.00	16	1.11	17	1.11
Mean		17	1.08	17	1.06	17	1.03
Deviation		0	0.07	1	0.07	1	0.09
Mean per yarn		0.089		0.088		0.086	
Percentage			36		35		34

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength pounds per inch	Silicated soap: Elongation inch	Soap: Breaking strength pounds per inch	Soap: Elongation inch	Sulfated alcohol: Breaking strength pounds per inch	Sulfated alcohol: Elongation inch
1	20	17	0.89	17	1.00	17	1.00
2		17	0.89	16	1.11	17	0.89
3		17	1.00	16	0.89	17	1.00
4		17	1.11	17	1.00	19	1.00
5		16	1.11	17	0.89	16	0.89
6		16	1.00	16	1.22	16	0.89
7		16	0.78	16	1.00	16	1.00
8		17	1.22	17	1.22	17	1.11
9		19	1.11	17	1.00	17	1.00
10		16	1.11	14	1.00	16	1.00
Mean		17	1.02	16	1.03	17	0.98
Deviation		1	0.11	1	0.11	1	0.05
Mean per yarn		0.087		0.083		0.087	
Percentage			34		34		33
1	30	16	1.22	16	1.11	16	1.00
2		17	1.11	15	1.22	16	0.89
3		17	1.00	15	1.22	16	0.89
4		17	1.11	17	1.11	16	0.89
5		16	1.00	17	1.22	17	1.22
6		16	0.89	17	0.89	16	0.89
7		16	0.89	16	1.22	16	1.11
8		16	0.89	15	1.11	17	1.22
9		17	1.00	15	1.22	16	1.11
10				17		16	1.11
Mean		16	1.01	16	1.15	16	1.03
Deviation		0	0.09	1	0.08	0	0.12
Mean per yarn		0.081		0.083		0.083	
Percentage			34		38		34

TABLE XLII. (Continued)

Determination	Washing	Silicated soap: Breaking strength	Silicated soap: Elongation	Soap: Breaking strength	Soap: Elongation	Sulfated alcohol: Breaking strength	Sulfated alcohol: Elongation
number	number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
1	40	16	1.00	16	1.11	15	1.11
2		16	1.11	16	1.11	15	1.22
3		16	0.67	16	1.22	13x	0.89x
4		16	1.22	17	1.22	14	0.89
5		16	1.00	16	1.22	15	1.11
6		14	0.89	16	1.11	15	1.00
7		15	1.00	14	1.11	17	1.11
8		17	1.22	17	1.44	15	1.00
9		14	1.00	14	1.11	17	1.33
10		14	1.00	14	1.22	16	1.11
Mean		15	1.01	16	1.19	15	1.10
Deviation		1	0.10	1	0.08	1	0.08
Mean per yarn		0.077		0.083		0.083	
Percentage			34		40		37
1	50	14	1.00	14	1.22	16	1.78
2		13	1.00	15	1.11	15	1.67
3		14	1.00	12	1.11	17	1.78
4		15	1.22	15	1.22	16	1.78
5		15	1.11	12	1.22	15	1.78
6		15	0.89	12	1.00	15	1.89
7		15	0.89	14	0.89	15	1.11
8		15	1.22	12	0.89	17	1.11
9		14	1.00	14	1.11	17	1.11
10		14	0.78	14	1.11	16	
Mean		14	1.01	13	1.09	16	1.56
Deviation		1	0.12	1	0.10	1	0.30
Mean per yarn		0.073		0.068		0.083	
Percentage			34		36		52

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength: pounds per inch	Silicated soap: Elongation: inch	Soap: Breaking strength: pounds per inch	Soap: Elongation: inch	Sulfated alcohol: Breaking strength: pounds per inch	Sulfated alcohol: Elongation: inch
4. Silk							
1	10	32	1.33	34	1.67	24	1.44
2		32	1.11	39	1.44	24	1.56
3		32	1.11	32	1.33	22	1.22
4		36	1.22	32	1.33	28	1.44
5		34	0.89	39	1.56	21	1.33
6		32	1.33	34	1.33	19	1.33
7		30	1.11	30	1.56	30	1.11
8				32	1.33	20	1.33
9				34	1.33	28	1.22
10				36		20	1.22
Mean		33	1.16	34	1.43	24	1.32
Deviation		2	0.12	2	0.11	3	0.10
Mean per yarn		0.138		0.142		0.100	
Percentage			39		48		44

TABLE XLII. (Continued)

Determination: number	Washing: number	Silicated soap: Breaking strength: pounds per inch	Silicated soap: Elongation: inch	Soap: Breaking strength: pounds per inch	Soap: Elongation: inch	Sulfated alcohol: Breaking strength: pounds per inch	Sulfated alcohol: Elongation: inch
1	20	36	1.78	34	1.33	17	1.11
2		38	1.78	32	1.33	23	1.00
3		34	1.56	32	1.11	22	0.89
4		37	1.33	30	1.22	17	0.89
5		32	1.44	30	1.22	19	0.78
6		36	1.44	34	1.22	17	0.89
7		36	1.44	34	1.33	19	
8				37	1.44	15	
9				34	1.22	19	
Mean		35	1.54	33	1.27	19	0.93
Deviation		2	0.14	2	0.08	2	0.09
Mean per yarn		0.146		0.138		0.079	
Percentage			51		42		31
1	30	34	1.44	32	1.33	12	
2		32	1.56	34	1.22	10	
3		39	1.22	34	1.33	8	
4		34	1.33	34	1.33	17	
5		28	1.44	34	1.33	12	
6		30	1.33	32	1.11	17	
7		32	1.33	32	1.22	12	
8		30	1.22	34	1.22	17	
9		28				14	
10						10	
Mean		32	1.36	33	1.26	13	
Deviation		3	0.09	1	0.07	3	
Mean per yarn		0.133		0.138		0.054	
Percentage			45		42		

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength: pounds per inch	Silicated soap: Elongation: inch	Soap: Breaking strength: pounds per inch	Soap: Elongation: inch	Sulfated alcohol: Breaking strength: pounds per inch	Sulfated alcohol: Elongation: inch
1	40	36	1.44	32	1.22	10	0.56
2		28	1.56	32	1.22	10	0.56
3		36	1.22	37	1.33	11	0.67
4		37	1.00	30	1.22	10	0.56
5		34	1.44	34	1.22	11	0.67
6		32	1.33	34	1.11	11	0.67
7		30	1.33	34	1.22	11	0.56
8		34	1.33	32	1.22	10	0.56
9				30	1.22	10	0.67
10				30	1.33		
Mean		34	1.29	33	1.23	10	0.61
Deviation		2	0.13	2	0.04	0	0.06
Mean per yarn		0.142		0.138		0.042	
Percentage			43		41		20
1	50	32	1.44	30	1.00	6	0.44
2		34	1.33	28	1.11	6	0.44
3		37	1.33	30	1.11	4	0.56
4		34	1.44	32	1.11	6	0.56
5		34	1.33	30	1.22	6	0.56
6		32	1.22	30	1.44	7	0.44
7		30	1.22	26	1.22	2	0.44
8		34	1.11	24	1.22	4	0.44
9		34	1.11	24	1.00	5	0.44
10				22	1.00	6	0.44
Mean		33	1.28	28	1.14	5	0.48
Deviation		2	0.10	3	0.08	1	0.05
Mean per yarn		0.138		0.117		0.021	
Percentage			43		38		16

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength, pounds per inch	Silicated soap: Elongation, inch	Soap: Breaking strength, pounds per inch	Soap: Elongation, inch	Sulfated alcohol: Breaking strength, pounds per inch	Sulfated alcohol: Elongation, inch
5. Wild silk							
1	10	17	1.00	17	1.11	15	
2		20	1.22	20	1.11	16	1.00
3		17	0.67	21	1.22	17	1.11
4		19	1.22	21	1.11	17	0.89
5		20	0.78	21	1.11	20	1.22
6		19	1.33	21	1.22	19	1.11
7		19	1.00	21	1.11	17	1.00
8		22	1.11	21	1.11	19	1.11
9		17	0.89	21	1.11	16	0.89
10		22	1.11	17		10x	0.89x
Mean		19	1.03	20	1.13	17	1.04
Deviation		1	0.16	1	0.04	1	0.10
Mean per yarn		0.244		0.260		0.218	
Percentage			34		38		35

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength pounds per inch	Silicated soap: Elongation inch	Soap: Breaking strength pounds per inch	Soap: Elongation inch	Sulfated alcohol: Breaking strength pounds per inch	Sulfated alcohol: Elongation inch
1	20	10		17	0.78	12	
2		14	0.78	17	1.00	12	0.78
3		16	0.89	17	0.89	17	0.89
4		14	0.78	17	0.89	15	0.89
5		15	0.89	17	0.89	13	0.78
6		14	0.89	17	0.89	15	0.89
7		17	0.89	14	0.89	17	0.89
8		16	0.78	16	1.00	13	1.00
9		12	0.89	17	1.00		
10		16	0.78				
Mean		14	0.76	17	0.91	14	0.87
Deviation		2	0.08	0	0.06	2	0.06
Mean per yarn		0.182		0.215		0.179	
Percentage			25		30		29
1	30	13	0.67	14		12	
2		9	0.56	15	0.78	12	0.78
3		14	0.78	15	0.89	12	0.56
4		13	0.78	15	0.89	12	0.67
5		10	0.56	15	0.89	12	0.67
6		12	0.78	13	0.78	12	0.78
7		10	0.78	16	0.89	12	0.67
8		12	0.78	16	0.89	10	0.67
9		12	0.67	16	0.89	13	0.78
10		12	0.67	16	0.78	10	0.89
Mean		12	0.70	15	0.77	12	0.65
Deviation		1	0.08	1	0.08	1	0.09
Mean per yarn		0.154		0.192		0.154	
Percentage			23		26		22

TABLE XLII. (Continued)

Determination	Washing	Silicated soap: Breaking strength	Silicated soap: Elongation	Soap: Breaking strength	Soap: Elongation	Sulfated alcohol: Breaking strength	Sulfated alcohol: Elongation
number	number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
1	40	8	0.67	12	0.67	8	
2		10	0.56	10	0.67	9	0.67
3		10	0.67	10	0.33	10	0.67
4		12	0.56	10	0.56	10	0.67
5		8	0.44	10	0.67	10	0.44
6		6	0.67	10	0.33	8	0.56
7		12	0.67	10	0.67	10	0.56
8		10	0.56	12	0.78	8	0.56
9		6	0.56	12	0.78	10	0.67
10		8		10	0.67	10	
Mean		9	0.60	11	0.61	9	0.60
Deviation		2	0.07	1	0.13	1	0.07
Mean per yarn		0.115		0.141		0.115	
Percentage			20		20		20
1	50	6	0.33	8		4	
2		4	0.33	8	0.67	6	0.56
3		6	0.33	8	0.67	6	0.56
4		6	0.33	8	0.56	6	0.56
5		2	0.44	8	0.56	6	0.44
6		6	0.44	8	0.56	6	0.56
7		4	0.44	8	0.67	6	0.56
8		4	0.33	8	0.89	6	0.56
9		6	0.44			6	0.56
10		4	0.44			6	0.56
Mean		5	0.39	8	0.65	6	0.55
Deviation		1	0.06	0	0.08	0	0.02
Mean per yarn		0.065		0.101		0.077	
Percentage			13		22		18

TABLE XLII. (Continued)

Determination:	Washing:	Silicated soap		Soap		Sulfated alcohol	
		Breaking: strength:	Elongation	Breaking: strength:	Elongation	Breaking: strength:	Elongation
number	number	pounds per inch	inch	pounds per inch	inch	pounds per inch	inch
6. Wool							
1	10	28	2.22	24	2.11	28	2.00
2		26	2.00	22	2.00	26	2.00
3		26	1.89	22	2.00	22	2.11
4		26	1.78	22	1.89	28	1.78
5		28	2.11	24	2.11	26	2.00
6		26	2.00	24	2.11	26	2.00
7		26	2.00	24	2.22	26	1.89
8		28	2.00	22	2.11	28	2.00
9		24		22	2.22	26	2.00
10				22	2.11	26	
Mean		26	2.00	23	2.09	26	1.98
Deviation		1	0.07	1	0.07	1	0.06
Mean per yarn		0.813		0.767		0.839	
Percentage			67		70		66

TABLE XLII. (Contimued)

Determination number	Washing number	Silicated soap: Breaking strength pounds per inch	Silicated soap: Elongation inch	Soap: Breaking strength pounds per inch	Soap: Elongation inch	Sulfated alcohol: Breaking strength pounds per inch	Sulfated alcohol: Elongation inch
1	20	24	1.89	24	2.33	24	2.00
2		24	1.89	26	2.11	24	2.00
3		26	1.89	24	2.22	24	2.11
4		22	1.89	22	2.11	28	1.89
5		24	2.11	26	2.11	26	2.11
6		26	2.11	22	2.11	24	1.89
7		26	2.33	24	2.11	26	1.78
8		28	1.89	21	2.11	26	1.89
9		24	2.33	26	2.00	22	
10		26	2.00			30	
Mean		25	2.03	24	2.13	25	1.96
Deviation		1	0.15	2	0.06	2	0.10
Mean per yarn		0.781		0.727		0.781	
Percentage			68		71		65
1	30	28	2.00	22	2.33	22	2.22
2		24	1.89	24	2.11	24	2.11
3		22	1.89	24	2.22	26	2.00
4		26	2.00	22	2.11	22	2.22
5		24	2.00	26	2.33	24	2.00
6		24	2.00	24	2.11	24	2.00
7		26	2.22	26	2.11	24	2.00
8		26	2.00	28	2.11	24	
9		24	1.89	26	2.11	24	
10		26	2.11	26			
Mean		25	2.00	25	2.17	24	2.08
Deviation-		1	0.07	2	0.08	1	0.08
Mean per yarn		0.735		0.715		0.774	
Percentage			67		72		69

TABLE XLII. (Continued)

Determination number	Washing number	Silicated soap: Breaking strength: pounds per inch	Silicated soap: Elongation: inch	Soap: Breaking strength: pounds per inch	Soap: Elongation: inch	Sulfated alcohol: Breaking strength: pounds per inch	Sulfated alcohol: Elongation: inch
1	40	24	2.33	22	2.00	26	1.89
2		24	2.33	24	1.89	28	2.00
3		24	2.22	24	2.00	26	2.00
4		22	2.33	24	1.89	26	1.89
5		24	2.00	24	1.89	24	1.78
6		22	2.11	24	1.78	26	1.89
7		22	1.89	24	1.89	28	1.78
8		22	2.00	24	1.78	24	2.11
9						24	1.78
Mean		23	2.15	24	1.89	26	1.90
Deviation		1	0.15	0	0.06	1	0.09
Mean per yarn		0.676		0.667		0.765	
Percentage			72		63		63
1	50	24	2.00	24	2.00	24	1.67
2		28	2.00	26	1.89	30	1.89
3		26	2.22	26	2.00	24	2.00
4		24	2.00	24	2.00	26	2.11
5		22	2.11	22	2.11	26	2.11
6		24	2.00	26	1.89	24	2.00
7		26	1.78	26	2.00	30	1.89
8		24	2.11	22	1.89	28	2.11
9				24		26	1.78
Mean		25	2.03	24	1.97	26	1.95
Deviation		1	0.09	1	0.06	2	0.09
Mean per yarn		0.676		0.667		0.743	
Percentage			68		66		65

TABLE XLIII. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE SULFUR OF FABRICS

Determination number	Detergent	Washing number	Fabric gram	Barium sulfate gram	Total sulfur percentage of fabric	Sulfate sulfur percentage of fabric
4. Silk						
	none	0			0.00*	
1	sulfated	10	3.3835	0.0337		0.14
2	alcohol		2.6124	0.0256		0.13
3			2.9027	0.0300		0.14
Mean					0.14	0.14
Deviation						0.00
1		20	2.2020	0.0270		0.17
2			2.3183	0.0275		0.16
Mean					0.17	0.17
Deviation						0.01
1		30	3.6287	0.0557		0.21
2			2.2820	0.0349		0.21
3			2.3356	0.0319		0.19
Mean					0.20	0.20
Deviation						0.01
1		40	2.7056	0.0379		0.19
2			2.2410	0.0262		0.16
Mean					0.18	0.18
Deviation						0.02
1		50	2.1431	0.0326		0.21
2			1.9774	0.0217		0.15
Mean					0.18	0.18
Deviation						0.03
5. Wild silk						
	none	0			0.00	

* Silk and wild silk washed with silicated soap or soap gave no test for sulfur; cellulosic fabrics washed with silicated soap, soap, or sulfated alcohol gave no test for sulfur.

TABLE XLIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Barium sulfate gram	Total sulfur percentage of fabric	Sulfate sulfur percentage of fabric
1	sulfated alcohol	10	0.6427	0.0095	0.20	0.20
1		20	0.8492	0.0066	0.11	0.11
1		30	0.6308	0.0022		0.06
2				0.0000		0.00
Mean					0.03	0.03
Deviation						0.03
1		40		0.0000	0.00	0.00
1		50	0.6729	0.0050		0.10
2			0.6349	0.0043		0.09
Mean					0.10	0.10
Deviation						0.01
6. Wool						
1	none	0	2.9766	0.7788	3.59	
2			3.4114	0.8897	3.58	
Mean					3.59	0.00*
Deviation					0.01	
1	silicated soap	10	4.6111	1.1994	3.57	
2			4.3902	1.1404	3.57	
3			4.4684	1.1600	3.57	
Mean					3.57	
Deviation					0.00	
1		20	2.8516	0.7434	3.58	
2			2.7725	0.7197	3.57	
Mean					3.58	
Deviation					0.01	
1		30	2.7872	0.7320	3.61	
2			2.8880	0.7488	3.56	
Mean					3.59	
Deviation					0.03	

* Wool washed with silicated soap or soap gave no test for sulfate sulfur.

TABLE XLIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Barium sulfate gram	Total sulfur percentage of fabric	Sulfate sulfur percentage of fabric
1	silicated	40	2.8739	0.7373	3.53	
2	soap		2.7821	0.7072	3.49	
3			2.8352	0.7378	3.58	
Mean					3.53	
Deviation					0.03	
1		50	3.0308	0.7738	3.51	
2			2.7577	0.7127	3.55	
Mean					3.53	
Deviation					0.02	
1	soap	10	4.2520	1.0906	3.52	
2			3.7537	0.9606	3.51	
Mean					3.52	
Deviation					0.01	
1		20	2.7744	0.7172	3.56	
2			2.1750	0.5634	3.56	
3			2.6636	0.6995	3.61	
Mean					3.58	
Deviation					0.02	
1		30	3.2366	0.8425	3.58	
2			3.4471	0.8842	3.52	
3			2.4554	0.6415	3.59	
Mean					3.56	
Deviation					0.03	
1		40	2.2914	0.5876	3.52	
2			2.5081	0.6404	3.51	
3			2.6392	0.6770	3.52	
Mean					3.52	
Deviation					0.00	
1		50	2.8400	0.7291	3.53	
2			2.9022	0.7439	3.52	
3			2.9408	0.7637	3.57	
Mean					3.54	
Deviation					0.02	

TABLE XLIII. (Continued)

Determination number	Detergent	Washing number	Fabric gram	Barium sulfate gram	Total sulfur percentage of fabric	Sulfate sulfur percentage of fabric
1	sulfated	10	3.7269	0.9976	3.68	
2	alcohol		3.6373	0.9639	3.64	
3			3.7770	1.0087	3.67	
4			3.5716	0.0601		0.23
5			3.5521	0.0535		0.21
6			3.6690	0.0573		0.21
Mean					3.66	0.22
Deviation					0.02	0.01
1		20	4.4664	1.2147	3.74	
2			3.1470	0.8631	3.77	
3			3.3650	0.9143	3.73	
4			3.6216	0.0772		0.29
5			3.5278	0.0834		0.32
6			3.7803	0.0740		0.27
Mean					3.75	0.29
Deviation					0.02	0.02
1		30	3.9302	1.0941	3.82	
2			3.9375	1.0542	3.68	
3			4.0449	1.1042	3.75	
4			3.8949	0.0823		0.29
5			3.3100	0.0659		0.27
6			3.4400	0.0730		0.29
Mean					3.75	0.28
Deviation					0.05	0.01
1		40	4.4875	1.2848	3.93	
2			3.6240	1.0299	3.90	
3			3.8268	1.0793	3.87	
4			4.1432	0.1546		0.51
5			3.6286	0.1192		0.45
6			3.3174	0.1157		0.48
Mean					3.90	0.48
Deviation					0.02	0.02
1		50	2.6823	0.7706	3.98	
2			2.9786	0.8674	4.00	
3			3.7108	1.0618	3.93	
4			2.7182	0.1112		0.57
5			2.4920	0.0950		0.52
6			3.3106	0.1358		0.56
Mean					3.97	0.55
Deviation					0.03	0.02

TABLE XLIV. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE WEIGHT OF FABRICS

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1. Cellulose						
1	none	0	2.92	37.375*	9.114	3.81
2			2.89		9.080	3.84
3			3.00		9.256	3.77
Mean						3.81
Deviation						0.02
1	silicated soap	10	3.10		9.885	3.41
2			3.02		9.210	3.26x**
3			3.06		9.795	3.42
Mean						3.42
Deviation						0.01
1		20	3.08		9.649	3.43
2			3.13		9.859	3.45
3			3.25		10.351	3.49
Mean						3.46
Deviation						0.02
1		30	3.01		9.346	3.32
2			3.01		9.382	3.34
3			2.99		9.275	3.31
Mean						3.32
Deviation						0.01
1		40	1.98		6.148	3.36
2			1.72		5.421	3.41
3			2.08		6.430	3.34
Mean						3.37
Deviation						0.03

* Full width of fabric is not repeated.
** Rejected observation

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1	silicated soap	50	2.06		6.665	3.46
2			1.84		5.840	3.39
3			2.04		6.472	3.39
Mean						3.41
Deviation						0.03
1	soap	10	1.76		5.620	3.41
2			2.13		6.814	3.42
3			2.09		6.772	3.46
Mean						3.43
Deviation						0.02
1		20	1.96		6.152	3.35
2			1.86		5.830	3.35
3			2.06		6.717	3.48
Mean						3.39
Deviation						0.06
1		30	1.86		6.032	3.42
2			2.03		6.420	3.34
3			1.99		6.398	3.39
Mean						3.38
Deviation						0.03
1		40	2.14		6.604	3.37
2			1.99		6.092	3.27
3			2.04		6.325	3.31
Mean						3.32
Deviation						0.03
1		50	2.01		6.511	3.37
2			1.80		5.891	3.41
3			2.05		6.460	3.36
Mean						3.38
Deviation						0.02
1	sulfated alcohol	10	2.06		6.624	3.43
2			1.76		6.103	3.70x
3			2.26		6.749	3.19
Mean						3.31
Deviation						0.12

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length: inch	Width: inch	Weight: gram	Weight: ounces per square yard original fabric
1	sulfated	20	1.93		6.111	3.38
2	alcohol		2.03		6.513	3.43
3			1.92		5.976	3.32
Mean						3.38
Deviation						0.04
1		30	1.93		6.016	3.33
2			1.97		6.120	3.32
3			2.03		6.171	3.25
Mean						3.30
Deviation						0.03
1		40	2.12		6.679	3.36
2			2.06		6.504	3.37
3			1.97		6.222	3.37
Mean						3.37
Deviation						0.00
1		50	2.08		6.579	3.38
2			1.91		5.597	3.13
3			2.12		7.130	3.59
Mean						3.37
Deviation						0.16
2. Regenerated cellulose						
1	none	0	3.13	35.50	6.972	2.87
2			3.03		6.789	2.89
3			2.99		6.635	2.86
Mean						2.87
Deviation						0.01
1	silicated	10	2.86		7.081	2.90
2	soap		2.72		6.753	2.91
3			2.96		7.430	2.94
Mean						2.92
Deviation						0.02

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length: inch	Width: inch	Weight: gram	Weight: ounces per square yard original fabric
1	silicated	20	3.01		7.510	2.87
2	soap		2.94		7.280	2.85
3			2.81		6.979	2.86
Mean						2.86
Deviation						0.01
1		30	1.89		4.660	2.94
2			1.51		3.730	2.95
3			2.01		4.943	2.93
Mean						2.94
Deviation						0.01
1		40	1.24		2.993	2.93
2			1.13		2.751	2.96
3			1.33		3.299	3.01
Mean						2.97
Deviation						0.03
1		50	1.15		2.880	2.99
2			1.11		2.763	2.97
3			1.29		3.171	2.93
Mean						2.96
Deviation						0.02
1	soap	10	1.23		3.002	2.86
2			1.26		3.175	2.95
3			1.39		3.556	2.99
Mean						2.93
Deviation						0.05
1		20	1.21		3.050	2.95
2			1.88		4.699	2.93
3			1.71		4.348	2.98
Mean						2.95
Deviation						0.02
1		30	1.53		3.740	2.91
2			1.36		3.391	2.97
3			1.14		2.811	2.94
Mean						2.94
Deviation						0.02

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length: inch	Width: inch	Weight: gram	Weight: ounces per square yard original fabric
1	soap	40	1.34		3.392	3.02
2			1.40		3.396	2.96
3			1.13		2.795	2.95
Mean						2.98
Deviation						0.03
1		50	2.03		5.006	2.94
2			1.79		4.563	3.04
3			1.98		4.903	2.95
Mean						2.98
Deviation						0.04
1	sulfated alcohol	10	1.68		4.096	2.91
2			1.93		4.710	2.91
3			1.86		4.500	2.88
Mean						2.90
Deviation						0.01
1		20	1.49		3.693	2.90
2			1.93		4.674	2.83
3			2.00		4.785	2.80
Mean						2.84
Deviation						0.04
1		30	1.40		3.358	2.82
2			1.51		3.584	2.83
3			1.39		3.282	2.82
Mean						2.82
Deviation						0.00
1		40	1.48		3.604	2.90
2			1.42		3.441	2.89
3			1.15		2.713	2.81
Mean						2.87
Deviation						0.04
1		50	1.17		2.754	2.81
2			1.28		3.104	2.89
3			1.40		3.356	2.87
Mean						2.86
Deviation						0.03

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length: inch	Width: inch	Weight: gram	Weight: ounces per square yard original fabric
3. Cellulose acetate						
1	none	0	2.75	39.33	6.860	2.90
2			2.91		7.240	2.89
3			2.83		6.906	2.84
Mean						2.88
Deviation						0.02
1	silicated soap	10	3.10		8.270	2.87
2			2.61		6.913	2.82
Mean						2.85
Deviation						0.03
1		20	3.03		8.142	2.84
2			3.08		8.206	2.82
Mean						2.83
Deviation						0.01
1		30	3.00		8.211	2.85
2			3.06		8.294	2.83
Mean						2.84
Deviation						0.01
1		40	1.27		3.632	2.90
2			1.13		3.170	2.84
Mean						2.87
Deviation						0.03
1		50	1.43		4.097	2.86
2			1.23		3.383	2.75
3			1.41		3.899	2.76
Mean						2.79
Deviation						0.05
1	soap	10	1.13		3.170	2.92
2			1.34		3.758	2.92
3			1.39		3.781	2.84
Mean						2.89
Deviation						0.04

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1	soap	20	1.14		3.207	2.85
2			1.44		4.116	2.89
3			1.41		3.910	2.81
Mean						2.85
Deviation						0.03
1		30	1.33		3.896	2.84
2			1.55		4.536	2.84
3			1.20		3.466	2.81
Mean						2.83
Deviation						0.01
1		40	1.16		3.409	2.82
2			1.53		4.480	2.81
3			1.17		3.370	2.76
Mean						2.80
Deviation						0.02
1		50	2.51		7.181	2.74
2			1.94		5.774	2.85
3			2.10		6.040	2.76
Mean						2.78
Deviation						0.04
1	sulfated alcohol	10	2.25		5.678	2.75
2			1.90		5.136	2.95
3			2.23		5.615	2.75
Mean						2.82
Deviation						0.09
1		20	1.47		4.040	2.82
2			1.18		3.240	2.82
3			1.48		4.094	2.84
Mean						2.83
Deviation						0.01
1		30	1.53		4.336	2.83
2			1.46		4.270	2.85
3			1.10		3.064	2.78
Mean						2.82
Deviation						0.03

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length: inch	Width: inch	Weight: gram	Weight: ounces per square yard original fabric
1	sulfated alcohol	40	1.44		4.081	2.83
2			1.15		3.263	2.83
3			1.39		4.042	2.90
Mean						2.85
Deviation						0.03
1		50	1.54		4.576	2.88
2			1.34		3.915	2.84
3			1.13		3.129	2.69
Mean						2.86
Deviation						0.08
4. Silk						
1	none	0	2.95	32.68	10.592	5.03
2			2.97		11.016	5.20
3			2.91		10.654	5.02
Mean						5.08
Deviation						0.08
1	silicated soap	10	1.24		4.727	5.43
2			1.44		5.384	5.33
3			1.40		5.243	5.33
Mean						5.36
Deviation						0.04
1		20	1.39		5.174	5.39
2			1.18		4.412	5.41
3			1.36		5.092	5.42
Mean						5.41
Deviation						0.01
1		30	1.94		7.400	5.43
2			1.86		6.907	5.29
3			1.94		7.212	5.30
Mean						5.34
Deviation						0.07
1		40	1.89		6.826	5.31
2			1.94		6.936	5.26
3			2.08		7.689	5.44
Mean						5.34
Deviation						0.07

TABLE XLIV. (Continued)

Determi-nation number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1	silicated soap	50	1.89		6.903	5.29
2			2.03		7.626	5.44
3			1.86		6.707	5.22
Mean						5.32
Deviation						0.08
1	soap	10	1.38		5.065	5.23
2			1.26		4.881	5.52
3			1.36		4.993	5.23
Mean						5.33
Deviation						0.13
1		20	1.19		4.556	5.45
2			1.59		6.005	5.38
3			1.51		5.598	5.28
Mean						5.37
Deviation						0.06
1		30	1.35		4.850	5.38
2			1.29		4.809	5.58
3			1.68		6.046	5.39
Mean						5.45
Deviation						0.09
1		40	2.09		7.522	5.21
2			1.84		6.907	5.44
3			1.81		6.804	5.44
Mean						5.36
Deviation						0.10
1		50	1.78		6.563	5.43
2			2.03		7.585	5.50
3			1.94		6.989	5.30
Mean						5.41
Deviation						0.07
1	sulfated alcohol	10	1.46		5.500	5.46
2			1.34		5.232	5.65
3			1.42		5.301	5.41
Mean						5.51
Deviation						0.10

TABLE XLIV. (Contimued)

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1	sulfated	20	1.45		5.588	5.31
2	alcohol		1.49		5.831	5.40
3			1.50		5.700	5.24
Mean						5.32
Deviation						0.06
1		30	1.87		6.728	5.30
2			1.51		5.422	5.29
3			1.53		5.439	5.23
Mean						5.27
Deviation						0.03
1		40	1.39		5.237	5.46
2			1.36		4.895	5.21
3			1.21		4.570	5.47
Mean						5.38
Deviation						0.12
1		50	1.64		5.604	5.03
2			1.48		5.293	5.39
3			1.36		5.073	5.49
Mean						5.30
Deviation						0.18
5. Wild silk						
1	none	0	4.00	33.5	4.146	1.41
2			4.06	31.5	3.931	1.41
3			3.98	33.5	4.473	1.53
Mean						1.45
Deviation						0.05
1		10	3.78		3.289	1.14
2			3.89		3.335	1.12
3			3.91		3.378	1.13
Mean						1.13
Deviation						0.01

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1	silicated	20	3.90		3.278	1.07
2	soap		4.01		3.805	1.20
3			4.00		3.717	1.18
Mean						1.15
Deviation						0.05
1		30	4.09		3.782	1.20
2			3.82		3.409	1.15
3			3.86		3.522	1.17
Mean						1.17
Deviation						0.02
1		40	3.61		3.060	1.09
2			3.68		3.222	1.13
3			3.81		3.051	1.03
Mean						1.08
Deviation						0.04
1		50	3.86		3.155	1.07
2			3.82		3.126	1.07
3			3.89		2.970	1.00
Mean						1.05
Deviation						0.03
1	soap	10	2.03		1.671	1.03
2			1.64		1.437	1.09
3			1.84		1.521	1.16
Mean						1.09
Deviation						0.04
1		20	1.81		1.637	1.16
2			1.75		1.879	1.38x
3			1.83		1.649	1.13
Mean						1.15
Deviation						0.01
1		30	1.86		1.665	1.17
2			1.79		1.640	1.20
3			1.71		1.464	1.12
Mean						1.16
Deviation						0.03

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1	soap	40	2.09		2.092	1.29x
2			1.97		1.761	1.15
3			1.84		1.632	1.14
Mean						1.15
Deviation						0.01
1		50	1.90		1.737	1.23
2			1.71		1.457	1.17
3			1.88		1.627	1.16
Mean						1.19
Deviation						0.03
1	sulfated alcohol	10	1.80		1.733	1.26
2			2.00		1.907	1.24
3			1.81		1.821	1.31
Mean						1.27
Deviation						0.03
1		20	1.69		1.507	1.13
2			1.88		1.658	1.12
3			1.85		1.628	1.12
Mean						1.12
Deviation						0.00
1		30	1.85		1.545	1.07
2			1.81		1.515	1.08
3			1.72		1.531	1.14
Mean						1.10
Deviation						0.04
1		40	1.83		1.730	1.20
2			1.91		1.948	1.29
3			2.09		1.965	1.19
Mean						1.23
Deviation						0.04
1		50	1.94		1.789	1.19
2			1.65		1.586	1.23
3			1.89		1.670	1.14
Mean						1.19
Deviation						0.03

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
6. Wool						
1	none	0	3.74	29.73	23.843	9.80
2			4.08		25.550	9.63
3			3.89		24.580	9.72
Mean						9.72
Deviation						0.06
1	silicated soap	10	3.90		25.304	10.66
2			3.79		24.158	10.48
3			3.91		24.954	10.49
Mean						10.54
Deviation						0.08
1		20	3.02		19.240	10.47
2			2.99		19.040	10.47
3			3.03		19.420	10.53
Mean						10.49
Deviation						0.03
1		30	1.81		12.052	10.94
2			1.98		13.126	10.90
3			1.90		12.409	10.73
Mean						10.86
Deviation						0.08
1		40	1.45		9.687	10.98
2			1.46		9.695	10.91
3			1.24		8.137	10.79
Mean						10.89
Deviation						0.07
1		50	1.99		13.432	10.75
2			1.80		12.143	10.72
3			1.89		12.820	10.78
Mean						10.75
Deviation						0.02

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length: inch	Width: inch	Weight: gram	Weight: ounces per square yard original fabric
1	soap	10	1.29		8.249	10.51
2			1.29		8.274	10.54
3			1.31		8.478	10.64
Mean						10.56
Deviation						0.05
1		20	1.44		9.265	10.57
2			1.29		8.425	10.73
3			1.31		8.528	10.70
Mean						10.67
Deviation						0.06
1		30	1.96		12.377	10.75
2			1.94		12.266	10.76
3			1.71		10.765	10.72
Mean						10.74
Deviation						0.02
1		40	1.94		12.502	10.59
2			1.81		11.593	10.50
3			1.96		12.679	10.63
Mean						10.57
Deviation						0.05
1		50	1.71		11.312	10.87
2			1.76		11.422	10.67
3			1.92		12.667	10.84
Mean						10.79
Deviation						0.08
1	sulfated alcohol	10	1.91		12.002	9.98
2			1.91		11.966	9.95
3			1.82		11.516	10.00
Mean						9.98
Deviation						0.02
1		20	1.45		9.368	10.62
2			1.28		8.191	10.52
3			1.44		9.295	10.61
Mean						10.58
Deviation						0.04

TABLE XLIV. (Continued)

Determination number	Detergent	Washing number	Length inch	Width inch	Weight gram	Weight ounces per square yard original fabric
1	sulfated alcohol	30	1.63		10.451	10.54
2			1.55		10.208	10.57
3			1.58		10.417	10.84
Mean						10.65
Deviation						0.13
1		40	1.85		11.925	10.59
2			1.85		12.128	10.77
3			1.93		12.772	10.88
Mean						10.75
Deviation						0.10
1		50	1.90		12.587	10.53
2			2.00		13.279	10.55
3			1.70		11.366	10.62
Mean						10.57
Deviation						0.04

DISCUSSION OF RESULTS

The effect of repeated washing with 0.5 percent of a neutral olive-oil soap (page 125) in distilled water on undyed plain-woven cellulose, regenerated cellulose, cellulose acetate, silk, wild silk, and wool (Table XXXVI), as compared with that of a silicated soap (page 125) and that of a sulfated alcohol (page 125) has been studied by analysis of the new fabrics and their residues after ten, twenty, thirty, forty, and fifty washings, for absorption of light (Table XLI), ash (Table XXXVIII), shrinkage (Table XXXIX), strength (Table XLII), and weight (Table XLIV), by analysis of the cellulose acetate for acetyl (Table XXXVII), the silks and wool for nitrogen (Table XL), the wool for total sulfur, and the silks and wool for sulfate sulfur (Table XLIII).

All fabrics washed with sulfated alcohol developed a green tint, more pronounced in the proteic fabrics and probably caused by a trace of copper in the distilled water (24). The unbleached cotton broadcloth was bleached more by the silicated soap than by soap. The darkening of the wild silk pongee is explained in part by the loss of its starchy sizing (Table XLVIII).

The percentage of acetyl in the cellulose-acetate rayon faille taffeta increased by 0.5 percent in ten washings and then remained constant within the range of experimental error (Table XLV).

In the case of each detergent residual ash of cellulosic fabrics decreased and that of proteic fabrics increased with increasing number of washings (Table XLVI). Increase in residual ash was greatest for wild silk and wool with silicated soap and least for wool with sulfated alcohol.

Total nitrogen of the residual wild silks reflects the loss of non-nitrogenous sizing, that of silk and wool the increased weight of their residues (Table XLVII).

Variations in shrinkage of each unpressed fabric (Table XLIX) by the different detergents come within the mean deviations of its yarn counts; the comparatively high warp shrinkage of the cotton broadcloth and filling shrinkage of the rayon and silk crepes are relaxation shrinkages while much of that of the cellulose-acetate rayon faille taffeta is due to its drying in hard creases. The shrinkage of wool homespun by the sulfated alcohol is in marked contrast to the excessive shrinkage caused by an aromatic sulfonate (33).

The wet strength of all the fabrics decreased for each detergent with increasing number of washings (Table L). The residual strengths of the cellulose-acetate were slightly higher after washing in sulfated alcohol, and those of the regenerated-cellulose rayon crepe after washing in silicated soap. Sulfated alcohol greatly decreased the strength of silk (76 percent in fifty washings) below that brought about by silicated soap (ten percent) or soap (24 percent) and reduced that of wild silk (74 percent) nearly to that brought about by silicated soap (78 percent). Grempe (51) has described a fabric as practically unusable after the loss of half its original strength. This attack on silk is in decided contrast to that of an aromatic sulfonate* (4.0 percent organic sulfur and 60 percent sodium sulfate) and neither ascribable to inorganic salt nor initial acidity. In contrast to the behavior of silk with sulfated alcohol, wool lost but eleven percent of its strength in fifty washings with sulfated alcohol, compared to losses of nineteen percent with silicated soap and 21 percent with soap.

The residual sulfur of wools washed with silicated soap or soap remained constant and that of wool washed with sulfated alcohol increased with increasing number of washings as did its sulfate sulfur. Lower and more nearly constant quantities of sulfate sulfur were absorbed from the sulfated alcohol by silk and wild silk although none was taken up by the cellulosic fabrics (Table LI).

The relatively large losses in weight (corrected for the effect of shrinkage, Table LII) of the cotton and wild silk fabrics are explained by their loss of sizing. The lower absorption of cellulose acetate, shown by its failure to gain in weight with any of the detergents, is a

* unpublished work done in this laboratory

contrast to the slight gain in weight of regenerated cellulose washed with silicated soap or soap. Wool increased in weight more than silk and to nearly the same extent with each of the three detergents. Discrepancies among corresponding values for weight of fabric may be due to the different hygroscopicities of a fabric washed with the different detergents.

TABLE XLV. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE ACETYL OF CELLULOSE ACETATE

Washing number	Silicated soap percentage	Soap percentage	Sulfated alcohol percentage
0	38.59	38.59	38.59
10	39.06	39.17	39.10
20	39.02	39.22	39.18
30	39.02	39.23	39.10
40	39.23	39.27	39.21
50	39.22	39.27	39.21

TABLE XLVI. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE ASH OF FABRICS

Fabric	Washing number	Silicated soap percentage	Soap percentage	Sulfated alcohol percentage
1. Cellulose	0	1.03	1.03	1.03
	10	0.27	0.24	0.22
	20	0.25	0.26	0.24
	30	0.37	0.23	0.22
	40	0.25	0.31	0.16
	50	0.33	0.34	0.20
2. Regenerated cellulose	0	0.63	0.63	0.63
	10	0.29	0.19	0.24
	20	0.45	0.23	0.16
	30	0.32	0.25	0.07
	40	0.31	0.20	0.10
	50	0.35	0.25	0.12
3. Cellulose acetate	0	0.13	0.13	0.13
	10	0.11	0.04	0.12
	20	0.12	0.02	0.07
	30	0.13	0.02	0.11
	40	0.10	0.00	0.08
	50	0.06	0.02	0.06
4. Silk	0	0.28	0.28	0.28
	10	0.72	0.48	0.48
	20	0.66	0.37	0.53
	30	0.78	0.50	0.59
	40	0.59	0.60	0.63
	50	0.57	0.63	0.76
5. Wild silk	0	0.57	0.57	0.57
	10	1.19	0.94	0.43
	20	1.22	0.93	0.75
	30	1.26	0.74	0.72
	40	1.34	0.83	0.78
	50	1.27	0.97	0.96
6. Wool	0	0.19	0.19	0.19
	10	0.94	0.92	0.42
	20	0.89	0.85	0.54
	30	1.15	0.90	0.68
	40	1.35	0.72	0.35
	50	0.64	0.75	0.36

TABLE XLVII. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE NITROGEN OF SILK, WILD SILK, AND WOOL

Fabric	Washing number	Silicated soap percentage	Soap percentage	Sulfated alcohol percentage
4. Silk	0	18.70	18.70	18.70
	10	18.42	18.60	18.48
	20	18.57	18.42	18.28
	30	18.49	18.57	18.32
	40	18.56	18.54	18.28
	50	18.46	18.40	18.20
5. Wild silk	0	15.13	15.13	15.13
	10	18.03	18.51	17.99
	20	17.95	18.53	18.12
	30	17.99	18.48	18.29
	40	18.06	18.30	18.07
	50	18.03	18.50	18.11
6. Wool	0	16.54	16.54	16.54
	10	16.35	16.39	16.39
	20	16.40	16.46	16.24
	30	16.53	16.40	16.29
	40	16.33	16.47	16.04
	50	16.31	16.34	15.82

TABLE XLVIII. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE PERCENTAGE OF LIGHT ABSORBED BY FABRICS

Fabric	Washing number	Silicated soap percentage	Soap percentage	Sulfated alcohol percentage
1. Cellulose	0	20	20	20
	10	17	18	20
	20	17	18	20
	30	16	18	21
	40	16	18	21
	50	16	18	22
2. Regenerated cellulose	0	20	20	20
	10	19	20	27
	20	19	20	20
	30	16	19	20
	40	15	22	20
	50	16	24	x
3. Cellulose acetate	0	16	16	16
	10	12	13	13
	20	x	13	12
	30	x	12	13
	40	12	13	12
	50	12	13	12
4. Silk	0	26	26	26
	10	24	24	27
	20	22	25	30
	30	23	25	35
	40	23	24	34
	50	26	27	40
5. Wild silk	0	35	35	35
	10	50	52	49
	20	46	51	54
	30	47	50	55
	40	x	50	56
	50	x	48	56
6. Wool	0	30	30	30
	10	28	30	31
	20	28	x	37
	30	29	31	37
	40	31	31	38
	50	32	31	45

x Residual strips of fabric were too narrow to be measured in the reflectometer.

TABLE XLIX. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE SHRINKAGE OF FABRICS

Fabric	Washing	Warp			Filling		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
	number	percentage	percentage	percentage	percentage	percentage	percentage
1. Cellulose	10	14	14	14	1	1	1
	20	12	14	14	2	1	1
	30	14	17	14	2	1	1
	40	13	14	14	3	3	2
	50	14	17	14	3	2	2
2. Regenerated cellulose	10	10	10	8	2	2	2
	20	12	10	10	2	2	2
	30	8	6	8	2	2	2
	40	6	8	8	2	2	2
	50	8	8	8	2	2	2
3. Cellulose acetate	10	8	11	7	4	6	8
	20	10	15	13	7	5	7
	30	11	20	16	7	5	5
	40	15	21	16	7	5	5
	50	16	21	20	5	5	5
4. Silk	10	-2	-2	-3	8	8	8
	20	-3	-2	-2	8	8	8
	30	-2	-6	-5	8	8	8
	40	-5	-3	-3	8	8	8
	50	-3	-5	-5	8	8	8

TABLE XLIX. (Continued)

Fabric	Washing	Warp			Filling		
		Silicated soap	Soap	Sulfated alcohol	Silicated soap	Soap	Sulfated alcohol
	number	percentage	percentage	percentage	percentage	percentage	percentage
5. Wild silk	10	5	6	5	4	3	4
	20	8	6	8	3	5	4
	30	6	5	6	4	4	4
	40	6	9	8	4	4	4
	50	5	2	6	3	5	4
6. Wool	10	-6	-10	-3	3	-3	0
	20	-6	-6	-6	3	6	3
	30	-6	-10	-6	10	13	0
	40	-6	-6	-6	10	16	10
	50	-3	-6	-3	19	16	13

TABLE L. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE WET WARP STRENGTH OF FABRICS

Fabric	Washing number	Silicated soap percentage of original	Soap percentage of original	Sulfated alcohol percentage of original
1. Cellulose	10	75	70	73
	20	69	70	73
	30	71	66	74
	40	73	62	72
	50	65	61	72
2. Regenerated cellulose	10	87	85	94
	20	92	82	91
	30	89	81	82
	40	85	84	81
	50	86	78	76
3. Cellulose acetate	10	96	95	92
	20	94	89	94
	30	87	89	89
	40	83	89	89
	50	78	73	89
4. Silk	10	90	93	65
	20	95	90	52
	30	87	90	35
	40	90	90	27
	50	92	76	14
5. Wild silk	10	83	89	74
	20	62	73	61
	30	53	66	53
	40	39	48	39
	50	22	34	26
6. Wool	10	97	91	100
	20	93	87	93
	30	88	85	92
	40	81	79	91
	50	81	79	89

TABLE LI. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE SULFUR OF FABRICS

Washing	Total sulfur			Sulfate sulfur		
	Silicated soap	Soap	Sulfated alcohol	Sulfated alcohol		
number	percentage of wool	percentage of wool	percentage of wool	percentage of wool	percentage of silk	percentage of wild silk
0	3.59	3.59	3.59	0.00	0.00	0.00
10	3.57	3.52	3.66	0.22	0.14	0.20
20	3.58	3.58	3.75	0.29	0.17	0.11
30	3.59	3.56	3.75	0.28	0.20	0.03
40	3.53	3.52	3.90	0.48	0.18	0.00
50	3.53	3.54	3.97	0.55	0.18	0.10

TABLE LII. EFFECT OF SILICATED SOAP, SOAP, AND SULFATED ALCOHOL ON THE WEIGHT OF FABRICS

Fabric	Washing number	Silicated soap: ounces per square yard original fabric	Silicated soap: percentage of original fabric	Soap: ounces per square yard original fabric	Soap: percentage of original fabric	Sulfated alcohol: ounces per square yard original fabric	Sulfated alcohol: percentage of original fabric
1. Cellulose	0	3.81	100	3.81	100	3.81	100
	10	3.42	90	3.43	90	3.31	87
	20	3.46	91	3.39	89	3.38	89
	30	3.32	87	3.38	89	3.30	87
	40	3.37	88	3.32	87	3.37	88
	50	3.41	90	3.38	89	3.37	88
2. Regenerated cellulose	0	2.87	100	2.87	100	2.87	100
	10	2.92	101	2.93	102	2.90	101
	20	2.86	100	2.95	103	2.84	99
	30	2.94	102	2.94	102	2.82	98
	40	2.97	103	2.98	104	2.87	100
	50	2.96	103	2.98	104	2.86	100
3. Cellulose acetate	0	2.88	100	2.88	100	2.88	100
	10	2.85	99	2.89	100	2.82	98
	20	2.83	98	2.85	99	2.83	98
	30	2.84	99	2.83	98	2.82	98
	40	2.87	100	2.80	97	2.85	99
	50	2.79	97	2.78	97	2.86	97

TABLE LII. (Continued)

Fabric	Washing number	Silicated soap: ounces per square yard original fabric	Silicated soap: percentage of original fabric	Soap: ounces per square yard original fabric	Soap: percentage of original fabric	Sulfated alcohol: ounces per square yard original fabric	Sulfated alcohol: percentage of original fabric
4. Silk	0	5.08	100	5.08	100	5.08	100
	10	5.36	106	5.33	105	5.51	108
	20	5.41	106	5.37	106	5.32	105
	30	5.34	105	5.45	107	5.27	104
	40	5.34	105	5.36	106	5.38	106
	50	5.32	105	5.41	106	5.30	104
5. Wild silk	0	1.45	100	1.45	100	1.45	100
	10	1.13	78	1.09	75	1.27	88
	20	1.15	79	1.15	79	1.12	77
	30	1.17	81	1.16	80	1.10	76
	40	1.08	74	1.15	79	1.23	85
	50	1.05	72	1.19	82	1.19	82
6. Wool	0	9.72	100	9.72	100	9.72	100
	10	10.54	108	10.56	109	9.98	103
	20	10.49	108	10.67	110	10.58	109
	30	10.86	112	10.74	110	10.65	110
	40	10.89	112	10.57	109	10.75	111
	50	10.75	111	10.79	111	10.57	109

SUMMARY

1. Plain-woven cotton, regenerated-cellulose rayon, cellulose-acetate rayon, silk, wild silk, and wool were washed separately by hand in 0.5 percent solutions of neutral olive-oil soap, silicated soap, or sulfated alcohol for five minutes at room temperature, rinsed until the rinse no longer foamed and dried in air and diffused light at room temperature. After ten, twenty, thirty, forty, and fifty washings all the fabrics were analyzed for ash, percentage of light absorbed, shrinkage, wet warp breaking strength, elongation at breaking load, and weight. The silks and wool were analyzed for total nitrogen and sulfate sulfur, the wool for total sulfur, and the cellulose acetate for acetyl.

2. The acetyl value of the cellulose-acetate rayon increased by 0.5 percent in ten washings but then remained constant.

3. With each detergent the ash of the cellulosic fabrics decreased and that of the proteic fabrics increased with increasing number of washings. The increase in ash for wild silk and wool was greatest with silicated soap and least for wool with sulfated alcohol.

4. Total nitrogen of the residual wild silks shows loss of non-nitrogeneus sizing during washing, that of silk and wool the increased weight of the residual fabrics.

5. Repeated washings bleached cellulose, and this effect was greatest with silicated soap. Silk, wild silk, and wool became darker upon repeated washing with sulfated alcohol.

6. Fabrics other than wool shrank but little in any of the detergents.

7. The wet strength of all the fabrics decreased with increasing number of washings in each of the three detergents. The wet strength of silk decreased 76 percent with sulfated alcohol, ten percent with silicated soap and 24 percent with soap in fifty washings. Wild silk lost 74 percent of its wet strength with sulfated alcohol, and 78 percent with silicated soap in fifty washings; wool lost eleven percent of its wet strength with sulfated alcohol, nineteen percent with silicated soap, and 21 percent with soap in fifty washings.

8. The residual sulfur of wool washed with silicated soap or soap remained constant and that of wool washed with sulfated alcohol increased. Silk and wild silk also retained sulfate sulfur from the sulfated alcohol.

9. The loss in weight of the cotton and wild silk fabrics upon washing is explained by their loss of sizing. Regenerated cellulose, contrasted with cellulose acetate, gained slightly in weight upon washing. Wool gained more in weight than silk with each of the three detergents.

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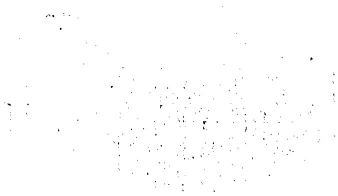
APPENDIX

NEW AND WASHED FABRICS

1. Cellulose*

Silicated soap   Soap   Sulfated alcohol

New



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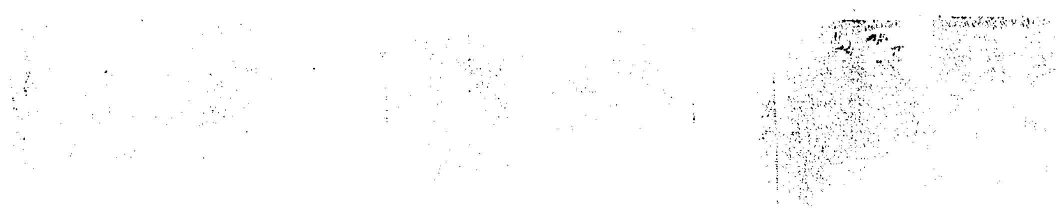

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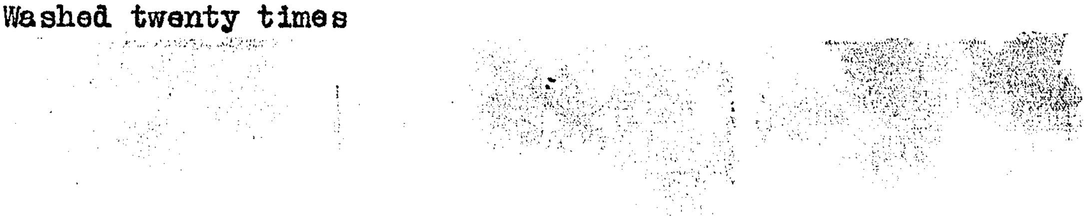
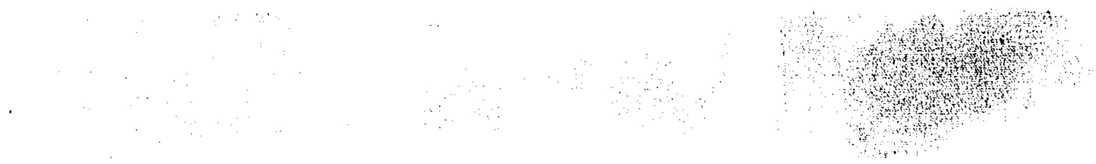


* Fabrics are mounted with warp yarns parallel to length of page.

Silicated soap	Soap	Sulfated alcohol

Washed thirty times



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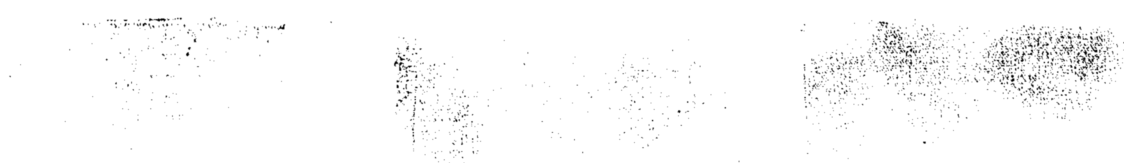

2. <u>Regenerated cellulose</u>

Silicated soap   Soap   Sulfated alcohol

New

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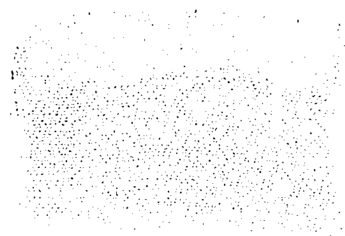

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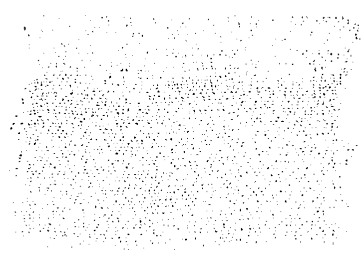
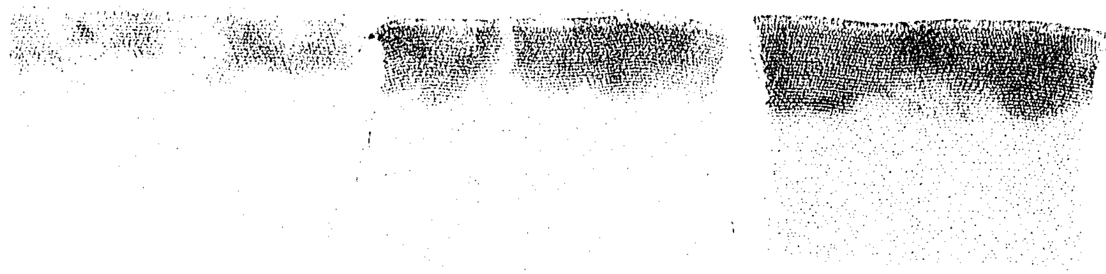


Silicated soap | Soap | Sulfated alcohol

Washed thirty times



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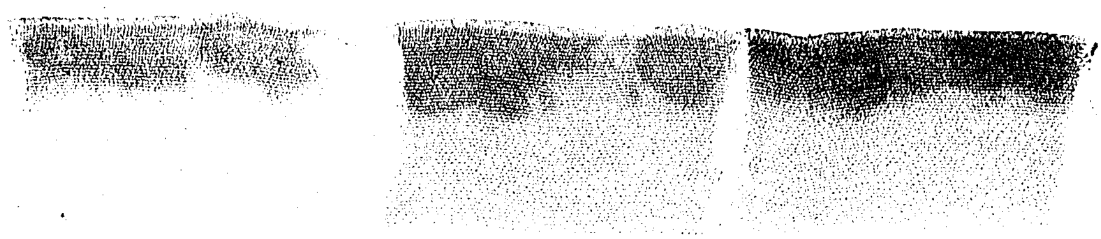

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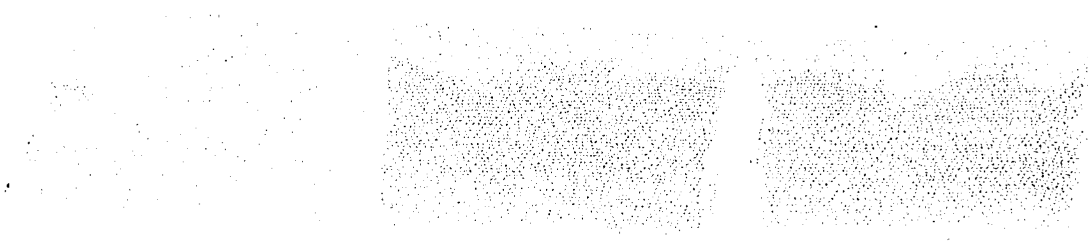


3. <u>Cellulose acetate</u>

	Silicated soap	Soap	Sulfated alcohol
New			
Washed ten times			
Washed twenty times			

Silicated soap	Soap	Sulfated alcohol

Washed thirty times

Washed forty times

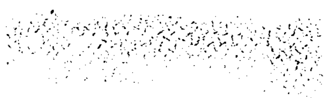
Washed fifty times

4. <u>Silk</u>

Silicated soap Soap Sulfated alcohol

New

Washed ten times



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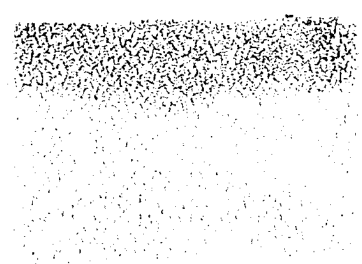
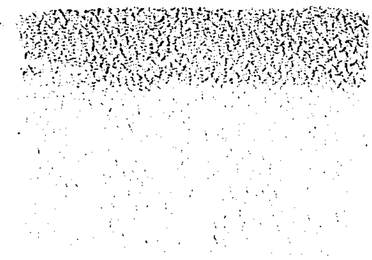


Silicated soap Soap Sulfated alcohol

Washed thirty times





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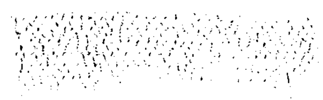
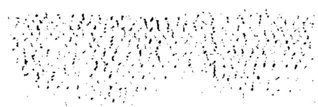
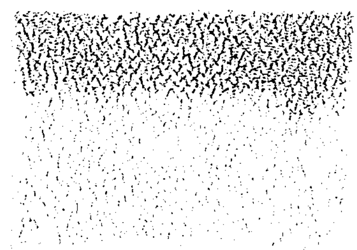

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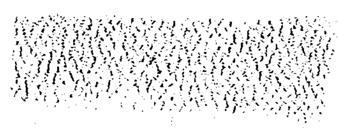
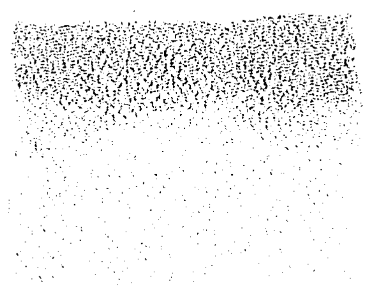
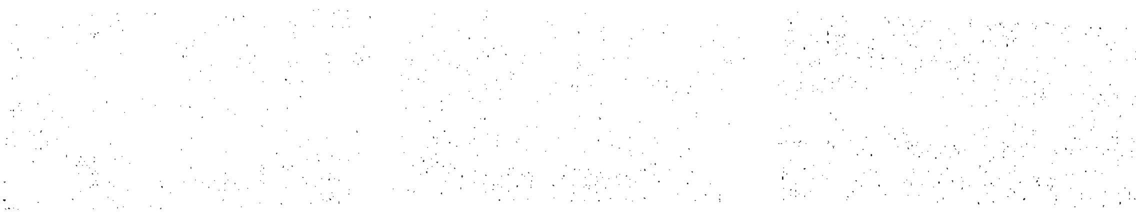



5. Wild silk

Silicated soap	Soap	Sulfated alcohol

New

Washed ten times



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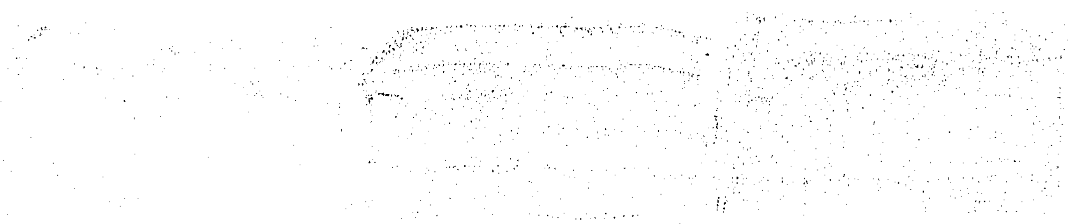
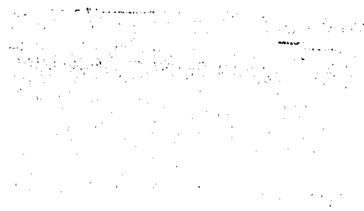
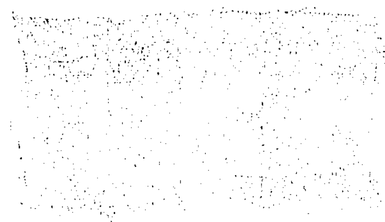


Silicated soap	Soap	Sulfated alcohol

Washed thirty times

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 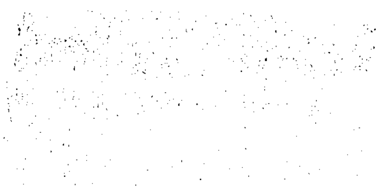 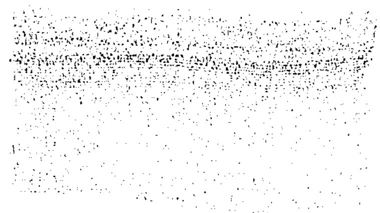

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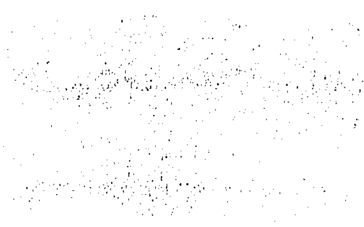
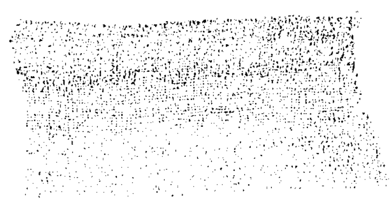
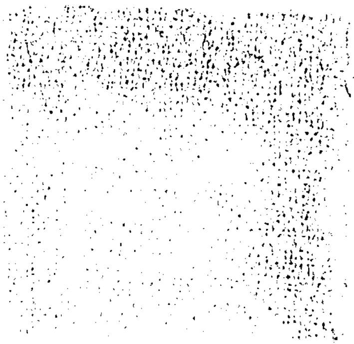
  

6. <u>Wool</u>

Silicated soap | Soap | Sulfated alcohol

New



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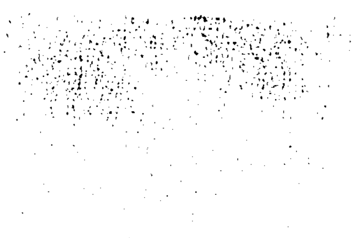

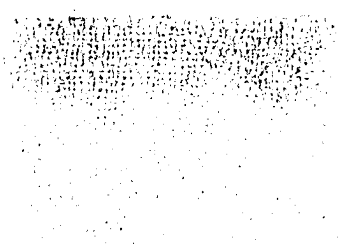

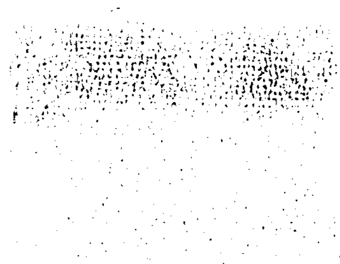

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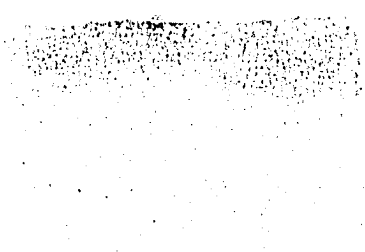

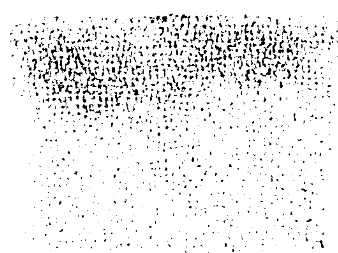

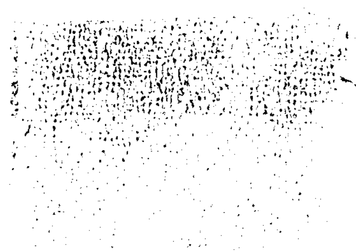

Silicated soap | Soap | Sulfated alcohol

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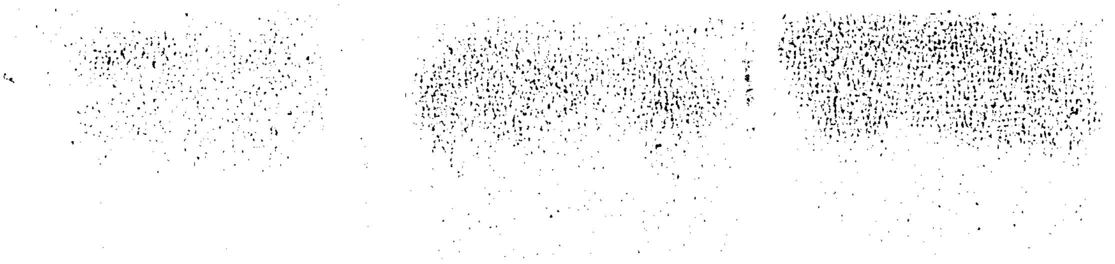

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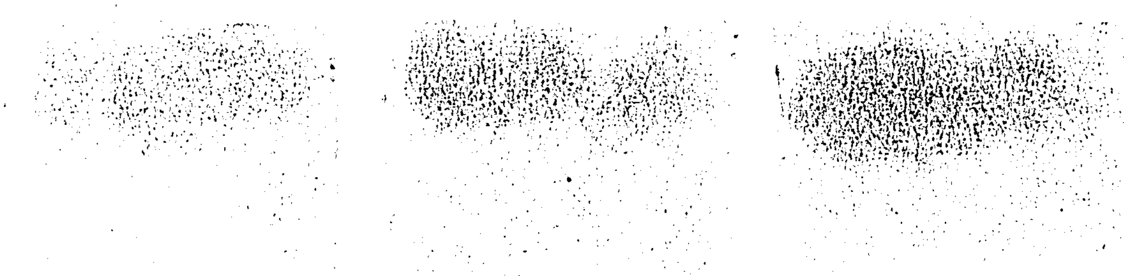

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