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A STUDY OF THE LAUNDERABILITY
OF SHEETS

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE
Ruth Marion Gerda Brotten
1948



This is to certify that the

thesis entitled

A Study of the Launderability of Sheets:
 4. Comparison of the Launderability of Three Grades
 of Sheets
 B. Comparison of the methods of Two Institution
 Laundries.
 presented by

Ruth Marion Gerda Broten

has been accepted towards fulfillment
 of the requirements for

M.S. degree in Institution Administration

Malvile Sperry Ehlers
 Major professor

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A STUDY OF THE LAUNDERABILITY OF SHEETS

- A. Comparison of the Launderability of three grades of Sheets.
- B. Comparison of the Methods of two Institution Laundries.

By

Ruth Marion Gerda Brotten

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Institution Administration

1948

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The writer wishes to express her appreciation and thanks to all who assisted in making this study possible: particularly to Professors Mabelle S. Ehlers and Hazel B. Strahan under whose supervision this work was done; to Dean Marie Dye for her suggestive criticism. Thanks are also due to the American Institute of Laundering for its cooperation in making the whiteness retention readings; to the Alley Linen Supply Co., J. C. Penney Co., Mr. Nicholls of Knapp's Department Store, and Mrs. Louise Carpenter for their contributions of the sheets used in the study; to Mr. Reynolds who supervised the laundering of the sheets at the Ingham County Sanatorium, and to Miss Gertrude Mueller who supervised the laundering at the Michigan State College Laundry; also to Mr. Jake Fasset, Director of the Service Department, American Hotel Association, for his cooperation.

TABLE OF CONTENTS

	<u>Page</u>
I. Introduction	1
II. Review of Literature	4
III. Methods of Procedure	14
A. Organization of the study	
B. Laundering Procedures	
C. Laboratory Tests	
1. Physical characteristics before laundering.	
2. Physical characteristics after laundering.	
IV. Discussion of Findings	31
V. Conclusion	45
VI. Summary	49
VII. Literature Cited	51
VIII. Appendix	53

INTRODUCTION

Of great concern to the institution manager is the life expectancy of institution equipment and furnishings. Careful consideration must be given to the purchasing and care of institution furnishings that will best serve their purpose for the longest period of time. Table linens and bed linens because of constant wear and laundering make necessary more frequent replacement than items of a more durable character. Comprehensive studies have been made by manufacturers, governmental, and other agencies on the qualities of sheets resulting in criteria for intelligent selection. Most of these studies, however, have been of more value to the homemaker than to the institution buyer. Linens are given more constant wear as well as different and more frequent laundering in institutions than in homes. It is logical then that studies of the comparative serviceability under normal conditions of use and care in institutions would be helpful to the institution buyer. E. A. Boss,² head of the Boss Hotels System, says that no salesman seems to know how many times an ordinary hotel sheet can be laundered under usual hotel conditions, nor does he know how many times a percale sheet will launder in comparison.

In selecting sheets, the homemaker is interested in the following factors: price, size, type, balance

in yarn count, tensile strength, the selvage, width of the hems, and the "finish" of the fabric. An institution buyer considers these same factors of serviceability and particularly considers the weight of the sheets which from the standpoint of laundering is a significant factor. The type of clientele which a hotel serves is also a determining factor in the selection of sheets of fine quality for hotel use as contrasted with the kinds of institutions. Hems of uniform width at the top and bottom are an economy because either end may be used at the top, thus distributing the wear more evenly, and saving time since it is unnecessary for the maids to look for the top or bottom of the sheet when making up the beds.

Because hotel and hospital bed linen is changed so often, it contains very little soil, and so does not require a strong washing solution. It needs little or no bleach and very little agitation in order to wash it clean and make it thoroughly sanitary, according to George Edwards,⁵ Maintenance Consultant to the American Hotel Association. He also stated that the length of service that linen gives cannot be computed in terms of weeks or months but in terms of the number of washings that it receives and the character of the washing.

The life span of linen usefulness in a hotel or other institution depends entirely upon: (1) the quality of the linen, and (2) the type of laundry treatment which it receives.

Many institutions operate their own laundries where the washing process can be controlled to suit their needs; others must send their linens out to commercial laundries where they are washed with all types of linen and all types of soil and where the washing formula may be set to remove soil with a maximum of pounding action and often with a strong bleach.

It seems desirable then, not only to have more technical data on the initial characteristics and performance values of sheets in constant service, but also how well they will withstand the laundry process and how they are affected by it. This may determine whether or not the laundry process is the best that can be used in order to give the sheet longer life.

This investigation was undertaken (1) to compare three types of sheets commonly used in institutions, and (2) to compare the washing procedures of the Michigan State College Laundry with another type of institution laundry.

REVIEW OF LITERATURE

Since the study is divided into two parts, the first, that of determining the types of sheets which are best suited for institution use, and the other, to compare the washing procedures of two types of institution laundries, the literature reviewed will also be divided into two parts. The first part will deal with studies that have been made on sheets and buying guides and the second on laundry processes.

Most of the studies that have been made on sheets have been undertaken primarily for the purpose of providing information for the homemaker. While institution buyers are also interested in many of the factors which influence the homemaker's choice, their criteria for selection is necessarily different.

N. G. Bennett¹ in a research study at the University of Missouri, on a comparison of qualities and prices of sheets available in Missouri stores states that the main problems confronting the consumer are:

1. How to determine and recognize desirable qualities.
2. What weight and kind of material to purchase in order to obtain maximum durability.
3. What type of sheet will be most economical to buy.

She goes on to say that the aids for the consumer in judging the quality of sheets are inspection, price, past experience, brands or trademarks, labels and laboratory testing.

Labels are becoming increasingly important and more informative. Many companies label their products, stating thread count, percent of sizing, tensile strength, and size. In Barbara Webster's¹⁴ study at Pennsylvania State College of a contribution to the development of a performance test for sheets, she concluded that labeling based on the performance of a sheet after repeated launderings would be of more value to the consumer than labels based on initial characteristics.

M. B. Hayes⁸, in a government study of the classification of sheets as an aid to consumer buying, suggested the following minimum specifications for five classes:

	Thread Warp	Count Filling	Breaking Strength (grab)*	Weight in Ounces per Square Yard
Percale	100	96	60	3.8 max.
Fine Count	86	82	60	3.7-4.0
Heavyweight	74	66	70	4.6 min.
Mediumweight	70	60	50	4.2
Lightweight	60	52	40	3.7

*A specimen four inches wide and six inches long is required for this test.

The Office of Price Administration, an agency set up during World War II, is responsible for mandatory labeling regulations on bed linens which are sold across retail counters.

Under this law sheets are classified according to four types rather than by name as in the study done by Hayes. A comparison of the minimum requirements as is shown in the O.P.A. table shows that type 180 falls between the percale and fine count sheets in the Hayes table, type 140 and heavyweight are the same, type 128 is comparable to mediumweight; and while type 112 and lightweight are the same. This table is on page 7.

V. G. Slutz,¹² at the University of Tennessee, made a study on the relationship of the physical characteristics of fibers found in wide bleached cotton sheeting to the durability of the fabrics as determined by laboratory tests and found that there was a tendency for sheeting to have more yarns per inch in the warp than in the filling, but that there was not a great deal of difference between the yarn number of the warp and the yarn number of the filling yarns. The shrinkage in the warp was greater than in the filling, and the warp yarns were stronger than the filling yarns, both in the dry and in the wet condition.

A greater number of investigations like these have been made for home use, but some experiments have

Labeling Rule on Sheets *1

*2	*3			
	<u>Type 180</u>	<u>Type 140</u>	<u>Type 128</u>	<u>Type 112</u>
Yarn Count per square inch	180	140	128	112
Weight per sq.yd. (ounces)	3.6	4.6	4.0	3.7
Tensile strength (grab) (pounds)				
Warp	60	70	55	45
Filling	60	70	55	45
Selvage	Tape	Tape	Tape	Tape
Plain hems 4-5- (total for both ends)	4"	4"	4"	4"
Stitches per inch *4 *5	14	14	14	14
Added sizing (max.)	4%	4%	6%	10%

*1 This table states minimum specifications (except) for added sizing) for each type.

*2 In the event of failure to meet minimum specifications for any given type as set forth in Table I, the goods shall be deemed to substandard and the applicable maximum price shall be determined pursuant to subparagraph (3) of paragraph (d).

*3 Bed linens having a finished thread count of less than 175 shall not be classified as Type 180 regardless of whether they meet all other specifications of that type.

*4 & *5 Not applicable to brown sheeting.

been carried on in institutions. A two year test on hotel sheets conducted by Boss², in his hotels, was done to find which sheet would be the most economical for hotel use and at the same time provide a satisfactory sheet for the guest. Results showed that the sheets considerably lighter in weight than muslin sheets but higher in thread count stood up under more than 300 periods of actual service and 300 washes in normal hotel use. The initial cost of these sheets was higher, but the greater original cost was offset by the reduced cost of laundering over the lifetime of the sheet, because of its lighter weight and its relatively small loss in weight after continued periods of service and washings. He does not state that this sheet is percale, but the assumption is clear.

In Edward's⁶ study he found that sheets washed after each night of service lost only 40% of their strength after 125 washings. They were washed 170 times before any breaking of the fabric was noted and 200 times before they were worn out.

Hays and Rogers⁹, in the Division of Textiles and Clothing, U. S. Bureau of Home Economics, concluded from their study on four classes of sheets during service, that one period of home wear was not equal to seven days of hotel wear, but was more nearly equal to three days of hotel wear. One period of home wear is regarded as equal to one week's use plus laundering, and seven of

hotel use equal to seven night's wear and seven launderings. They found that the amount of service given by a sheet is closely related to its filling breaking strength.

According to these investigations, the medium weight muslin sheet was found to give the least service, while the heavy weight muslin gave the best service.

Laundrying is a cleansing treatment which has to be repeated frequently during the life of an article. Articles to be laundered must be classified: (1) as to material of which they are made, (2) as to type of article, and (3) as to the amount of soil. Each classification needs special treatment.

R. E. V. Hampson⁷, Director of the British Launderers' Research Association states, in his article on the effects of laundrying processes on fabrics, that there are three features to observe for good washing: (1) the ability to detach dirt from the fabric, (2) the ability to suspend the dirt detached and prevent its redeposition, and (3) adequate means of removal of liquid from the machine in which the operation is performed. He says that the launderability of a fabric is its suitability for the whole process of laundrying, as carried out by recognized and proper methods.

The stages in the washing process and the purpose of each are also described by Hampson.

The first water in the laundry process is known

as the "break" of "breakdown" -- the temperature of the water is about 90-100°F., no soap is added, and very little mechanical agitation is given the washing load. The purpose of the "break" is to thoroughly wet the load, and to remove the large particles of dirt.

The first suds follows, and in this stage a large portion of the soil is easily removed. The temperature of the water is between 110-120°F., and a soap is used.

The second suds removes the soil which is more difficult to remove. The temperature is increased to 140°F., a soap is used, and more agitation is given the clothes.

The purpose of the third suds, when it is used, is to remove the more resistant soil. The temperature is increased, also the mechanical action.

Several rinses follow the sudsing operations. These remove the soap from the articles being washed.

Laundry chemicals are used in the washing procedure, all with the intention of making the articles white, and as near to their original color as possible. The clothes may be subjected to a chlorine bleach, by the addition of a dilute solution of sodium hypochlorite in the washing machine. B. Levitt¹¹ in his article on laundry chemicals says the most economical method is to make it from caustic soda and chlorine: $2\text{NaOH} \text{ \& } \text{Cl}_2$ --

NaOCl & NaCl & H_2O . The chemical reaction that takes place when chlorine bleaches is as follows: sodium hypochlorite being an unstable chemical when introduced into a hot solution quickly decomposes to liberate nascent oxygen and sodium chloride. The active oxygen bleaches and disinfects.

Laundry blueing may be used alone or in combination with acids or other chemicals. It is used to correct the yellowish tint which may remain in the clothes after washing.

A neutralizing agent or what the laundrymen call a "sour" is used in one of the rinses. It is important to use a neutralizer which will not weaken or "tender" the fabric since it dries in the clothes. T. D. Snell¹³ gives the following reasons for using a sour:

- (1) To neutralize the alkali from the soap, soap builders, and bleach used in previous steps.
- (2) To neutralize the natural alkalinity of the water supply, which is present as sodium bicarbonate after softening.
- (3) To remove stains, either those not removed in previous operations or those picked up during the process.

He says that sours are believed to be harmful to the strength of the fabric only when they are not rinsed

out thoroughly.

In a study of temperatures used in laundering at Pennsylvania State College, H. I. Carson³ found that a temperature of 82° to 85° C. was most effective for the removal of deeply embedded soil, and recommends a temperature of 60° to 62.8° C. as the most satisfactory at which to wash. He also found that in order to remove most stains in laundering, a low washing temperature is needed for removal of certain stains, followed by high washing temperature for removal of other stains -- particularly those containing some grease.

The formula set up by the State of Pennsylvania is found on page 13.

COMMONWEALTH OF PENNSYLVANIA

WASHING FORMULA

Bath	Water Level	Temperature	Suds Bath	Supplies	pH	Time Min.
1.	4"	100-110°F	Heavy suds ¹	C-54 comp	10.15	10
2.	4"	125-140°F	Heavy suds ²	C-55 comp	10.2	10
3.	4"	160°F	Heavy suds ²	C-55 comp	10.3	10
4.	4"	160°F	Heavy suds ²	C-55 comp ³ & bleach	10.7	10
5.	8"	160°F				5
6.	8"	160°F				5
7.	8"	160°F				5
8.	8"	125-140°F				5
9.	4"	125°F		Sour ⁴	5.9	5
10.	8"	Cold				5

1. 165 gms. of low titre soap, specification C-54 of the Commonwealth of Pennsylvania, composed of the following: 59-65% soap, 7-9% tri sodium phosphate, 10-14% sodium carbonate, and moisture and volatile matter 18%.
2. 100 gms. of high titre soap, specification C-55 of the Commonwealth of Pennsylvania, consisting of these components: 69% soap, 9% tri sodium phosphate, 7% sodium metasilicate, 14% sodium carbonate.
3. The bleach used was a 1% solution of sodium hypochlorite. An amount equivalent to 2 qts. of this diluted bleach solution was used for each 100# of dry fabric.
4. The sour used was sodium acid fluoride, with 335 cc of a solution made up of 30 gms. of the fluoride in one liter of distilled water.

METHODS OF PROCEDURE

A. Selection of the Sheets

Nine brands of sheets were used for this investigation. They were divided into three groups depending upon type, with three different brands of sheets in each group. The brands represented were: Forest City, Nationwide, Cannon, Utica, King, Dwight Anchor, Harmony House, Duracale, and Golden Dawn. Type refers to the thread count per inch. In this instance types 128, 140, and 180 were used. These types are referred to by the trade as mediumweight muslin, heavyweight muslin and utility percale, respectively. By using three types of sheets in this way, a better comparison could be made of their performance in institution use than if the study were confined to one quality.

The sheets were obtained from jobbers and individuals interested in the study. No manufacturer knew that the sheets were to be tested; therefore the quality was the same as any consumer buyer might have purchased on the open market, either at retail or wholesale price.

B. Making of the Test Pieces

Two sheets from each brand were cut into pieces 24" by 21" and then assembled to form a composite sheet.

No pieces were taken nearer the selvage than one tenth the width of the fabric which is in compliance with A.S.T.M.⁴ requirements for the breaking strength tests. The pieces were made 24" long in the direction of the warp and 20" wide in the direction of the filling yarns or weft. In order to insure that no section would lose its identity, each piece was labeled with its full name in the lower left hand corner with a laundry marking pen.

Pieces from each of the nine sheets to be tested were combined into a composite sheet. Test specimens from each type and brand were sewed together in such a way that the composite sheet was made up of three sections. Each section represented each of the three brands of the same thread count. Eighteen such sheets were made, and in each the sheet samples were placed in the same relative position. The samples were joined by flat felled seams to cover all of the raw edges and the sides were hemmed to a width of approximately one-half inch. (See diagram of composite sheet on page 16).

The purpose of combining the specimen pieces into composite sheets was to make certain that samples of all of the sheets tested were given the same treatment. Therefore the various samples had the same number of washings and ironings with the same handling throughout.

Figure 1

Nationwide 128	Utica 140	Golden Dawn 180
Cannon 128	Dwight Anchor 140	Duracale 180
Forest City 128	King 140	Harmony House 180

Diagram of Composite Sheet

Two laundries participated in the study, the Ingham County Sanitorium, representing an institution laundry, and the Michigan State College Laundry, which, while an institution laundry, is more nearly comparable to a commercial laundry in that it operates on a much larger scale and the type of laundry done is more varied. The Ingham County Sanitorium is a hospital for tubercular patients and the type of laundry done is primarily limited to uniforms, table linens, bed linens, and towels. The Michigan State College Laundry limits its work only to departments of the college and students and staff, which would constitute the laundering of uniforms, bed linens, table linens, towels, and personal apparel.

Of the eighteen composite sheets, eight were laundered at the Ingham County Sanitorium and eight at the Michigan State College Laundry; two being kept as controls or for the testing of initial properties. At each laundry the sheets were washed for four different periods, each period consisting of 50 launderings.

Two sheets were withdrawn after each period of 50, 100, 150 and 200 launderings respectively. The two sheets, which were kept for initial testing, were laundered three times to remove all soluble sizing before testing for initial physical characteristics.

C. Laundering Procedures

1. Comparison of the methods used at Ingham County Sanitorium and at Michigan State College.

At Michigan State College the sheets were placed in the washer, an American Laundry machine, with any load of white clothes which happened to be ready for washing. They were given the same treatment as any load of clothes which came into the laundry in the ordinary run of business. The washwheel was loaded with a lot weighing approximately two hundred and seventy pounds. The first water, called the "break", has a temperature of about 100°F. and this wash runs for ten minutes. In the "break", about four quarts of soap* and one half pound of yellow** is added to eighty gallons of water. The next water is a hot suds with the temperature at 140°F. The soap solution is added after the washer is started and while the wheel is turning down, in order to get the solution into the water rather than upon the clothes. It also prevents splattering that would occur if it were added when the wheel was turning upward. The soap

* White Ribbon Soap Chips. Solution made of eight pounds of soap chips to 100 gallons of water.

**Wyandotte Yellow Hoop Soda. It is a tri-sodium phosphate base, builder and softener.

solution is used hot to enable it to make suds more easily and quickly. Eighty gallons of water is used for this suds and about two quarts of soap, and it runs for ten minutes.

This is followed by a second suds. The amount of water is the same, eighty gallons, and the running time ten minutes. The temperature is increased to 160°F. and the soap decreased to one quart.

The third and last suds is also run in eighty gallons of water for ten minutes at a temperature of 170°F.; one pint of soap is used, and two quarts of Ecco-Chor liquid bleach, a very weak bleach, is added*.

Three rinses follow in one hundred and fifteen gallons of water at a temperature of 170°F. for five minutes.

The fourth rinse is run in only sixty gallons of water at a temperature of 180°F. for five minutes and has two ounces of sour** added to it. The purpose of the sour is to neutralize the natural alkalinity of the water supply, which is present as sodium bicarbonate after softening. It also removes stains, either those not removed in previous operations or those picked up during the process.¹³

* About .2%

** Bluefix

The last rinse is done in one hundred and thirty-five gallons of cold water to which was added a blue*, and it is run for five minutes.

When the washing is finished, the clothes are loaded into a truck and taken to the extractor. After being loaded in it, the moisture is nearly all removed from the wash by whirling. The test sheets are then ready to go through the same washing procedure again.

The water used at the Michigan State College Laundry came from the College water supply which is derived from deep wells. It is zeolite softened at the College power plant to as nearly zero grains of hardness as possible.

The sheets laundered at the Ingham County Sanatorium were washed with the hospital sheets in one hundred and twenty-five pound loads in an American Cascade washwheel. The washer is smaller than the one used at the college laundry, consequently the loads washed were smaller.

The washing process begins with a three minute "break" in warm water, about 100⁰ F., and with one hundred and twenty inches of water in the washwheel. This is followed by the suds in five inches of water at 140⁰ F. for ten minutes, to which has been added an alkali,

* Speares' Solblue

orthosilicate, and one pound of powdered soap, Amber flakes*, and one pint of a one percent chlorine bleach.

The second suds is run for ten minutes in five inches of water at 165⁰F., with one-fourth pound Amber soap and one-half pound alkali.

The first rinse is done in five inches of water for three minutes at a temperature between 160-165⁰F., to which has been added one half pint of Calgon.**

This is followed by three more rinses in twelve inches of water for three minutes each at 165⁰F. The fifth rinse is done in warm water for five minutes. Sour*** is added to the next rinse in five inches of warm water for five minutes. Cold water is added to bring the water up to sixty inches in the washwheel, and the blue is added and run for five minutes.

Lansing city water is used which has three grains of hardness.

The washing formulas of the two laundries differ in a few respects. The college laundry runs three suds and five rinses, whereas the hospital laundry runs only two suds and seven rinses. The hospital laundry uses

* Amber Flakes--a yellow soap.

** Calgon--a complex molecularly dehydrated phosphate. Its reaction in solution is slightly acid towards soap, which makes it desirable to employ a buffering agent which will bring up its pH to 8.5.

*** Diamond Alkali Sour

a weak chlorine bleach in the suds and Calgon in the rinse. The amount of water used is about the same, but it is measured on a different basis since the washwheels are not the same size. A formula of the laundries is tabulated in the appendix.

D. Laboratory Tests

1. Yarn count and yarn twist. It was necessary to check the yarn count so that the investigator made certain that the sheets in this study met the specification set up for thread count as stated on their labels. The determinations were made on the new, unwashed sheets. The procedure used in determining the number of yarns per inch was carried out in accordance with A.S.T.M.⁴ A Suter Micrometer was used in counting the yarns in three places on the sheet for both warp and filling yarns. An average of these determinations was made and recorded.

The Suter Twist Tester was used to determine the number of twists per inch. Ten warp yarns and ten filling yarns were raveled from the new, unwashed sheets in such a manner as not to alter their twist. Each yarn was then securely clamped in place in the machine. The number of turns necessary to untwist and retwist the yarn until it broke was recorded in each case. For each of the nine original sheets tested, an average of ten

determinations was used in reporting the amount of twist per inch for the warp and filling yarns.

2. Tensile Strength. The samples for testing the tensile strength by the raveled-strip method were prepared according to directions set up by Federal Specifications, in the Commercial Standards Bulletin CS59-44. Two sets of five specimens one and one-fourth inches by six inches from each test sheet were cut with the longer dimension parallel to the warp and two similar sets of five specimens each parallel with the filling. Each strip was raveled to exactly one inch in width. No two strips were cut on the same yarns in the first set which was to be tested when dry. The second set of strips were cut along the same yarns as the first set, and these were to be tested when wet. By testing the same yarns wet and dry, a better comparison could be made of their strength.

The samples to be tested when wet were allowed to stand two hours or more in water at room temperature before testing.

The School of Home Economics at Michigan State College does not have a conditioning room. In order to keep the dry samples at a more nearly constant temperature and humidity so that the tensile strength would be uniform within one test sheet and throughout the study, the dry specimens were conditioned in a dessicator for twelve

hours before testing. A 36% solution of sulfuric acid was placed in the bottom of the dessicator, and a perforated porcelain plate held the samples in the center of the dessicator.

The machine used in testing the tensile strength was the Scott Tester. It is a pendulum type testing machine, electrically operated, and is built in such a way that one end of the specimen is held by a moving clamp operated at a constant speed while the other end is held by a clamp attached to a weighing mechanism. The number of pounds at which the specimen is broken is recorded on a scale.

3. Strength of the fabric based on tensile strength after abrasion. The wearability of a fabric can, to a certain extent, be measured by its resistance to abrasion. Laboratory tests have been conducted by the Fabric Research Laboratories, Inc. at Boston to discover certain physical properties which would determine the abrasion--resistance of a fabric. Ernest R. Kaswell¹⁰, of the Laboratories says results show the reduction in tensile strength provides the best known criterion for measuring extent of abrasion. The method consists of abrading portions of a fabric for varying numbers of cycles and then determining resulting strength losses.

The machine used in this study was the Taber Abrader. It is an electrically driven machine, consisting

of a turntable four inches in diameter, which rotates at a constant rate of speed in a horizontal plane. The fabric to be tested is securely fastened to this turntable. Two rubber emery composition wheels rest on the turntable in such a manner that they are free to rotate in a vertical plane. The lines of abrasion are in the form of two arcs crisscrossing each other which results in a circular path on the fabric. The turntable moves but the wheels do not. A counter records each cycle of the turntable. The rubber emery wheels should be dressed on emery paper for 225 cycles after every 500 cycles.

A test of this kind when performed on sheets should show a comparative rating for wearability. In order to compare one type of sheet with another, a constant number of abrasion cycles should be used to indicate wear rather than to allow the samples of the sheets to run for different lengths of time which would show varying degrees of wear. To set up this constant number it was necessary to know the abrasive resistance of each sheet in the study. In order to test the abrasive resistance, a sample of each sheet was run on the abrasion machine until it showed the first signs of wear and continued until a hole was produced. The point at which one yarn, either warp or filling, broke was regarded as the first sign of wear. The hole stage was at the point at which one warp and one filling yarn broke at the same spot.

Since the results of this experiment are based on the tensile strength of the abraded samples, there had to be enough strength left in those samples after abrasion so as to be recorded on the tensile tester. Therefore it was decided that in order to insure a sufficient amount of strength in the samples, it would be best to take the fabric with the least abrasive resistance, in other words, the lowest number of cycles, and subtract from that number 100. The arbitrary figure used as the constant number at which all of the remaining test samples would be run was 200 cycles. This left enough strength in the material for breaking and assured enough strength in the remaining samples for giving a fairly accurate comparison of the tensile strength after abrasion of all groups of sheets.

When the constant figure had been decided upon, three samples of each test sheet that had been washed 100 and 200 times in both laundries were run on the abrader, as well as samples from the control sheet which had been washed only three times for the removal of soluble sizing.

Modified A.S.T.M. strip samples were cut from the circular abraded fabric, and tensile strengths were determined.

The Scott tensile tester was used to record breaking strength, and the clamps were adjusted to a

one inch gauge length because each strip specimen measured one inch by two and one-half inches. The strips were allowed to stand in a dessicator, in which the humidity was controlled at 65% and the temperature at 77°F. for at least twelve hours before testing the breaking strength.

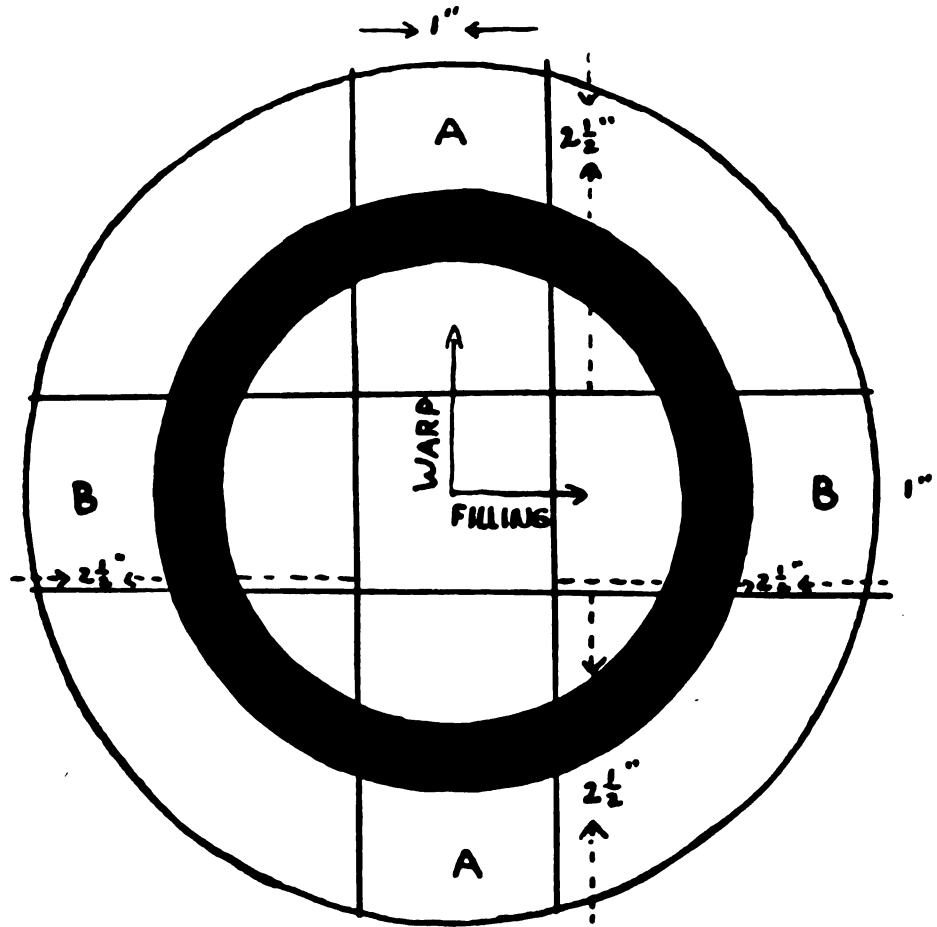
Figure 2 on page 28 shows the abraded path, size of the test strips, and the manner in which they were cut from the abraded fabric.

4. Whiteness retention. It was desirable to measure the whiteness retention of the sheets used in this study because some of the donors wished this information which is predictive as to the degree of original whiteness the fabric will retain. The laundries involved were also interested in whiteness retention as the color of the fabric might indicate the effect of the laundry procedures.

The Armour Research Laboratories in Chicago, Illinois, are authority for the statement that sizing and the application of heat are not the reasons for the yellowing of fabrics, but that it is more likely to be caused by the redeposition of soil during washing. This would indicate that whiteness retention is not so much dependent upon the manufacturing of the fabric as upon how it is laundered.

Since Michigan State College has no equipment for

Figure 11



A - Abrade fillinewise, test warpwise

B - Abrade warpwise, test fillinewise

Diagram of Abraded Fabric

measuring reflectancy in fabrics, and since both laundries involved are members of the American Institute of Laundering at Joliet, Illinois, the laboratories of the Institute were called upon to help with this test. These laboratories are equipped with a Hunter Multi-purpose Reflectometer which can be used for measuring the reflectancy of a fabric in terms of the reflection of magnesium oxide. For determining the whiteness retention of the sheets after various periods of laundering, it was necessary for them to have samples of the original fabric and of the different sheets after the various laundering periods. The whiteness retention of the washed samples was obtained by comparing the reflectancy of the washed sample with that of the original material.

For making these readings, samples ten inches by fifteen inches were required of each fabric. This size was necessary so that the fabric could be folded to obtain eight thicknesses for the reflectancy measurement.

5. Subjective Analysis. The human eye can measure to a slight extent certain qualities which make fabrics desirable or undesirable. In this study there are only a few things which the eye might measure, such as linting, color and wear. No specific criterion was set up for determining any of these. Comparisons of these factors were made on the new fabrics as well as after each period of laundering.

Linting can be noticed in two ways: (1) by the amount of nap or "fuzzing" which is raised on the fabric and can be seen and felt after various stages in laundering, and (2) by the amount of lint noted on the fabric during the abrasion test.

If there is a marked change in color, the eye will be able to perceive it when all of the fabrics are placed next to each other. It will not be possible to detect the degree of change in color, but if there is even a minor change, it can be seen.

The eye can also determine some signs of wear, especially holes throughout the material, and signs of wear along hem edges.

DISCUSSION OF RESULTS

The initial properties of the nine sheets used in this investigation are recorded in table 1, page 32.

Yarn Count and Yarn Twist

The count within each of the three types of sheets studied was found to be fairly well balanced, with one exception in the type 128 group where there was a difference of fourteen yarns more in the warp than in the filling.

All of the sheets met the minimum specifications for yarn count, and in every instance it was slightly higher than the count stated on the label, or as set up by the O.P.A. chart.

All sheets were made of single yarns with an S twist. Percales, as a group, had the highest twist per inch in both warp and filling yarns. Harmony House, with a twist of 21.4 in the warp and 18.2 in the filling was the highest in this group.

The amount of twist in the 128 count and 140 count sheets was very nearly the same. They ranged from a high of 18.9 twists per inch to 16.2 in the warp yarns, and a high of 14.8 and low of 12.1 in the filling.

In all cases the warp yarns had a higher number

TABLE I
INITIAL PROPERTIES OF SHEETS

	* I		I		* I		I		Whiteness Retention Measurements
	Yarn Count	Yarn Twist	Warp Filling	Warp Filling	Tensile Strength Per Pound	*2	Filling Dry Wet		
	Warp	Filling	Warp	Filling	Warp	Filling	Dry	Wet	
Cannon	70	60	S18.9	S14.5	41	51	47	53	85.1
Nationwide	70	61	S16.2	S12.1	39	58	49	61	84.2
Forest City	72	58	S18.0	S14.1	38	49	41	49	85.2
Dwight Anchor	74	68	S17.4	S13.2	51	59	46	60	82.7
King	76	70	S17.7	S14.8	36	48	49	58	82.1
Utica	74	68	S18.1	S13.7	37	45	46	47	83.3
Harmony House	95	91	S21.4	S18.2	33	44	33	45	87.3
Duracale	94	88	S20.9	S16.4	32	53	42	60	85.5
Golden Dawn	94	87	S18.2	S17.9	36	40	36	49	85.2

* Based on three readings

*1 Based on ten determinations

*2 Based on five determinations

of twists per inch than did the filling, although they varied from only one to four twists more. It is characteristic of all warp yarns to have a slightly higher twist than the filling yarns.

Tensile Strength

There is a noticeable difference in the tensile strength of sheets as set up by the O.P.A. ruling, which was mentioned previously in this study, and the finding in this investigation. The sheets tested here were lower in tensile strength than the standards set up in the O.P.A. ruling. This may be accounted for by the fact that the O.P.A. specifications are based on the grab method in testing strength which records a higher figure than the raveled strip method which was used in this test and were not conditioned according to requirements or defined by A.S.T.M. The initial tensile strength of the sheets in this study probably do conform to the minimum mandatory requirements for tensile strength.

In comparing the tensile strength of the laundered sheets, it was found that the readings varied only slightly. This was true of all of the types of sheets throughout the four periods of laundering, at both laundries. In some instances, the sheets laundered at the Michigan State College Laundry had a higher breaking strength than the same brand washed at the Ingham County Sanitorium, and

just as often the reverse was true. A chart showing the tensile strength readings is found in Table 5, in the appendix.

Of the sheets in the 128 count group, Nationwide had the highest tensile strength when new, and it remained the highest quite consistently throughout the four laundering periods at both laundries. Cannon, in the same group, ranked second highest in tensile strength when new and after the two-hundredth laundering. Forest City, also a type 128 sheet, had the lowest tensile strength of this group initially and throughout the test.

In the group of 140 counts, Dwight Anchor was found to have the highest tensile strength initially and after 50 laundrings at both laundries. King, in the same group, ranked second in strength when new and after 50 laundrings. Both of these sheets were high in strength after 100, 150 and 200 laundrings, and it is difficult to say which is the better of the two after these periods.

Utica, another type 140, had the lowest tensile strength of this group when new, and it remained consistently the lowest throughout the four laundering periods. Utica, also, had the lowest tensile strength of any sheet in the three types tested.

Of the sheets belonging to the 180 group, Duracale had the highest tensile strength initially and

consistently throughout the four laundering periods.

Golden Dawn, a 180 count, was found to have the second highest breaking strength of this group. In a few instances, however, it was the lowest while Harmony House was second. After most of the laundering periods, Harmony House had the lowest tensile strength.

The 140 and 180 count groups have a higher breaking strength than the 128's, with the exception of Utica in the 140 group which had lower strength readings than any of the 128's. There was little variation in strength between any of the groups.

The sheets with the highest tensile strength in each type were: Nationwide in type 128; Dwight Anchor in type 140; and Duracale in type 180.

Warp and filling strengths were found to be very close and proportional to the yarn count. The strength of the strips tested when wet was slightly higher than those tested when dry, as is characteristic of cotton fabrics.

An analysis of variance of the tensile strength, Table 2, page 36, shows that there is a highly significant difference between the brands in strength. There is also a highly significant difference between washing periods and in the interaction between brand and washing.

The percentage change in tensile strength of all sheets tested at both laundries was quite inconsistent.

TABLE 2

TENSILE STRENGTH MEASURED BY AN ANALYSIS OF VARIANCE

	S.S.	D.F.	M.S.	
Total	26,850.7	404		
Brands	7,279.5	8	909.94	$F_1 = 19.005^{**}$
Washings	13,369.7	8	1,671.21	$F_1 = 34.904^{**}$
Interaction between brand and washing	3,064.5	64	47.88	$F_0 = 4.946^{**}$
Error	3,137.0	324	9.68	
Washings	13,369.7	8		
Original vs. washed	63.9	1	63.9	
Laundries	3,379.5	1	3,379.5	$F_2 = 6.67^{n.s.}$
Periods	8,406.3	3	2,802.1	$F_2 = 5.53^{n.s.}$
L. x P.	1,520.0	3	506.7	$F_1 = 10.58^{**}$
B. x W.		64	47.88	
Brands				
Brand groups	1,233.5	2	616.8	$F_3 = 1^{n.s.}$
W. groups	6,046.0	6	1,007.7	$F_1 = 21.05^{**}$
B. x W.		64	47.88	

The average percentage change in breaking strength is shown in Table 6, in the appendix. It does not show that one laundry is superior to the other in the wear and tear on sheets.

The type 180 sheets showed the lowest percentage change in wet and dry breaking strength warpwise after 200 launderings at the College laundry, and the highest percentage change at the Sanatorium laundry. The type 128 sheets showed the highest percentage change in warp and filling, when wet and when dry at the College laundry, while at the Sanatorium laundry this group ranked between the type 140 and type 180 in the amount of change in tensile strength. Type 140 showed the lowest percentage change in strength at the Sanatorium laundry and at the College laundry this group ranked between the type 128 and type 180.

Most of the sheets gained in strength during the period of 50 launderings, and thereafter lost in strength. This is due to shrinkage during the first few washings in which the fibers of the yarn become more compact and therefore show a higher tensile strength. At the end of the 100th, 150th and 200th laundering the sheets at both show progressive loss in tensile strength.

Tensile Strength after Abrasion

An analysis of the readings of the tensile strength

after abrasion, Table 7, in the appendix, showed that Cannon and Nationwide, both type 128 sheets were equally as good in initial strength. One sheet may have been superior in strength at one laundry during one period, while the other sheet was high at the other laundry at the next period. Both of these sheets were high in tensile strength after the 100 and 200 launderings; so it is difficult to determine from the figures which is the better of the two. Of this group, however, Forest City had the lowest initial tensile strength after abrasion, and it remained the lowest throughout this test.

Of the sheets belonging to the 140 count group, King was found to have the highest initial strength in the filling while Dwight Anchor had the highest strength warpwise. After 100 launderings King still had the highest filling strength and Dwight Anchor the highest warp strength. Both were high in strength after 200 launderings; so again it is difficult to make a definite statement as to which of these two sheets is the better. Utica had the lowest strength of this group initially and throughout the test.

Initially, Golden Dawn a type 180, had the highest strength warpwise and Duracale fillingwise. After 100 and 200 launderings Duracale was the strongest of this group while Harmony House was stronger in warp strength but weaker in filling strength than Golden Dawn.

An analysis of the percentage change in tensile strength after abrasion, in the three groups of sheets, shows that the percentage loss was less in the warp strength of the type 180 sheets and in the filling strength of the 140 sheets. The percentage loss in the warpwise strength of type 180 ranged from 17.4 to 29.5, while the percentage loss in strength of the filling yarns of type 140 ranged from 8.5 to 38.8. There was a greater loss of strength in type 128 than in either of the other groups. The percentage loss in this group ranged from a low of 16.5 in the filling to a high of 53.0 in the warp. A table showing the percentage change in tensile strength after abrasion is found in Table 8, in the appendix.

The sheets laundered at the Ingham County Sanatorium showed a lower percentage change in breaking strength than those given the same treatment at the Michigan State College Laundry.

An analysis of variance, Table 3, page 40, shows that the variance in brands is highly significant in their reaction to tensile strength after abrasion.

The effect of laundry procedures was also found to be highly significant as with the interaction between brand and treatment. The analysis shows also that there is a greater variability of strength within one type than between the three types.

TABLE 3
TENSILE STRENGTH AFTER ABRASION AS MEASURED
BY AN ANALYSIS OF VARIANCE

	S.S.	D.F.	M.S.
Total	28,892	323	
Brands	5,470	8	683.8 $F_1 = 13.07^{**}$
Treatments	16,358	5	3271.6 $F_1 = 62.53^{**}$
B. x T.	2,093	40	52.32 $F_0 = 2.84^{**}$
Error	4,971	270	18.4
Treatments	16,358	5	
Unwashed vs. washed	13,212	1	252.5 ^{**}
Unwashed abr. vs. not abr.	675	1	12.90 ^{**}
Laundries	1,006	1	19.23 ^{**}
No. of washings	1,401	1	26.78 ^{**}
L. x W.	64	1	1.22 ^{n.s.}

Whiteness Retention

The American Institute of Laundering made the tests on whiteness retentions for this study. Table 9, in the appendix, shows the results of their investigation.

By count, the 180's retained their color, or whiteness, the best of the three groups, and the type 128's were the poorest in this respect.

In ranking the sheets according to their whiteness retention measurements it was found that Utica, a type 140, had the highest readings, or the best whiteness retention of any sheet, at every period of laundry and at both laundries. Harmony House, type 180, ranked second and Duracale and Golden Dawn, both type 180's, ranked third.

According to an analysis of variance, both the brand and number of washings are highly significant in determining whiteness. This is shown by the figures in Table 4, page 42.

The laundry at which the sheets were washed is highly significant in determining the whiteness retention. It was found that the Michigan State College Laundry was superior in this respect.

TABLE 4

WHITENESS RETENTION MEASURED BY AN ANALYSIS OF VARIANCE

	S.S.	D.F.	M.S.	
Total	86,230	80		
Brands	5,321	8	665.1	$F_1 = 10.2^{**}$
Washings	76,745	8	9593.0	$F_1 = 147.0^{**}$
B. x W.	4,164	64	65.06	
Between count	795	2	398.0	n.s
Within count	4,526	6	254.0	
Washed vs. unwashed	3,138	1	3138.0	$F_4 = 10.4^*$
Laundry	71,064	1	71064.0	$F_2 = 390.0^{**}$
No.Washings	1,998	3	666.0	$F_2 = 3.66^{n.s.}$
L. x N.	545	3	182.0	$F_3 = 5.81^{**}$
B. x W.(orig.)	1,752	56	31.3	
B. x W.(W vs.) (Unw.)	2,412	8	301.5	

Subjective Analysis

In comparing the types of sheets by sight and "hand"* the percale or type 180's had the best appearance and a smoother, silkier "hand" than any of the others. The 140's were coarser and heavier, and the 128's felt coarser but lighter in weight, due to the fact that they were not as firmly woven.

Signs of wear were found after 100 launderings at the Michigan State College Laundry. These were in the form of obvious breaks in the yarn of the Cannon, 128 count. At 150 launderings, these breaks had become definite holes.

Nationwide, also a 128 count, showed definite holes after 150 washings.

King, a 140 count, showed small holes and warp breaks at 150 launderings, as did Harmony House, a 180 count.

Among the sheets laundered at the Ingham County Sanatorium the only wear in the sheets was found in the Utica after 200 launderings, where definite breaks were found along the hems.

While samples of sheets were being abraded, it was noted the type 128's were very chalky and linty. The 140's had a tendency to be a little linty, and the

*"Hand" refers to the feel the fabric has when handled.

percales showed practically no linting.

As to color, the sheets all had the same appearance, when new. After each period of washing the color changed slightly. This change was not perceptible to the eye until the completion of the test, when all of the washed samples were placed together. It could then be seen that the sheets washed at the Ingham County Sanatorium had a slightly bluish cast, whereas the sheets laundered at Michigan State College had become creamy or yellowish in color.

After 200 launderings none of the sheets showed wear to the extent that the sheet would no longer give good service if it were in use. The appearance and "hand" of the sheets was still good at the end of four laundry periods, or the 200 launderings.

CONCLUSION

The investigator feels, after making this study, that both the Michigan State College Laundry and the Ingham County Sanatorium Laundry do good work and use a satisfactory washing formula. This is evidenced by the laboratory tests which were made.

Through an analysis of the data on initial characteristics and these same characteristics after 50, 100, 150 and 200 launderings, at each of the two laundries, it is the opinion of the investigator that the method or procedures used in one laundry are not superior to the other laundry. In the tensile strength test, for instance, an analysis of variance showed that the effect of the laundry procedure did not have a significant bearing on the tensile strength of the sheets. This can be seen, too, by examination of Table 5, which shows that at times a particular sheet may have had a higher breaking strength at one laundry than it did at the other, and again the opposite was true. Therefore, the washing processes at both of these laundries are similar in their effect upon the strength of the fabrics.

In the tensile strength after abrasion test, however, the sheets laundered at Michigan State College lost more strength than the sheets laundered at the Ingham

County Sanatorium. It appears, from this, that the procedures at the Ingham County Sanatorium are superior to those at Michigan State College. This is indicated by the analysis of variance, Table 3, and also by Tables 5 and 6 where one can compare the average of six tensile strength determinations and the percentage loss in strength of the sheets.

The sheets washed at Michigan State College Laundry proved to be superior in reflectancy measurements, as can be seen by Tables 4 and 9. At the end of the four laundry periods some sheets had higher reflectancy readings than the original. That is, some of the laundered sheets were actually whiter than they were before washing. This is surprising since it is expected that sheeting fabric will become grayed after a series of washings due to the re-deposition of soil. In this instance it is quite likely that the sheeting originally contained finishing material and blueing which would tend to reduce the reflectancy of the fabric. This reflectancy would improve to a maximum with successive washings, and would be expected to drop off as the washing progressed.

The investigator also feels that either type 140 or type 180 sheets would prove to be very serviceable for institutional use. The type of institution and clientele it accommodated would be the determining factors in the selection of their sheets. If price was a factor,

the cheaper sheet, which is the 140 count, would be the most practical buy. On the other hand a luxury hotel might prefer the finer quality of a percale sheet to the heavier duty muslins, which less expensive hotels or institutions might buy.

After a comparison of the results of the tensile strength tests on the three types of sheets studied, it can be stated that both thread count and brand are significant guides in determining service and strength of the sheets. In each type grouping of sheets there were some brands found to be stronger than others, such as Nationwide, type 128; Dwight Anchor and King, type 140's; and Duracale, type 180. Of the three groups the type 140's and 180's had a higher tensile strength than those of type 128.

The laboratory tests made after abrasion are comparable to tests made after the sheets have been worn and laundered. In this test one sheet from each group had a low tensile strength, and at the same time it was difficult to determine which of the other two belonging in the same group was better. Types 180 and 140 showed the lowest percentage change of the three types in the study. These factors indicate that brand is not as important a point in determining length of service and strength of a sheet as is the tensile strength and the thread count.

Type 180 sheets remained the whitest throughout 200 launderings, according to reflectancy measurements. This is probably due to the longer, finer, staple which is used in making the yarns for percales, and to the higher twist of the yarns.

Utica, a type 140, had the highest reflectancy measurements of any sheet, and since it had the lowest tensile strength of any sheet it may be due to over bleaching in the process of manufacturing.

While this study gives us a clue as to, the performance of two laundry procedures, specific differences between each cannot be stated. A more detailed laundry study would have to be made in order to determine these. More comprehensive studies which would provide a much larger sampling in both types and brands of sheets as well as cost factors would be of great assistance to the institutional buyer.

SUMMARY

This study was made (1) to compare three types of sheets commonly used in institutions and (2) to compare the washing procedures of the Michigan State College Laundry with that of another institution laundry.

Nine brands of sheets were used; three in each group, based on yarn counts of 128, 140 and 180, respectively.

Test sheets were cut into small sections, 21" by 24" and from these composite sheets were then made up, each one containing a section from each brand of sheets used in the investigation. Eighteen composite sheets were made eight of which were laundered at the Michigan State College Laundry and eight at the Ingham County Sanatorium Laundry. The remaining two were laundered three times to remove sizing, and then used as control sheets and for initial testing.

Both laundries washed the sheets for four periods consisting of 50 washings: 100 washings: 150 washings: of 200 washings respectively.

After each laundry period the sheets were tested in the laboratory for tensile strength, tensile strength after abrasion, and whiteness retention. Comparisons were then made with the initial characteristics of the sheets.

The procedures of the two laundries and their effect upon the serviceability of the sheets was found to be very similar. According to the results of the laboratory tests, the sheets with thread counts of 140 and 180 are the most practical for institution use.

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APPENDIX

WASHING FORMULA

Ingham County Sanatorium

Bath	Water Level	Temperature	Suds Bath	Supplies	Time (Min.)
1	120"	100°F.	Break		3
2	5"	140°F.	Suds	Alkali 1#Amber flakes 1 pt.bleach	10
3	5"	165°F.	Suds	$\frac{1}{4}$ # soap $\frac{1}{2}$ # alkali	10
4	5"	160-165°F.	Rinse	$\frac{1}{2}$ pt. Calgon	3
5	12"	165°F.	Rinse		3
6	12"	165°F.	Rinse		3
7	12"	165°F.	Rinse		3
8	12"	Warm	Rinse		5
9	5"	warm	Rinse	sour	5
10	60"	cold	Rinse	Blue	5

Michigan State College

1	80 gal.	100°F.	Break	4 qt.soap $\frac{1}{2}$ # yellow	10
2	80 gal.	140°F.	Suds	2 qt.soap	10
3	80 gal.	160°F.	Suds	1 qt.soap	10
4	80 gal.	170°F.	Suds	1 pt.soap 2 qt.bleach	10
5	115 gal.	170°F.	Rinse		5
6	115 gal.	170°F.	Rinse		5
7	115 gal.	170°F.	Rinse		5
8	60 gal.	180°F.	Rinse	2 oz.sour	5
9	135 gal.	cold	Rinse	Blue	5

TABLE 5a
DRY BREAKING STRENGTH IN POUNDS*

Brand	Laundry	50	100	150	200
		W.	F.	W.	F.
128 Count:					
Cannon	M.S.C.	41.0	50.2	35.6	45.4
	I.C.S.	47.8	49.6	45.8	46.2
	M.S.C.	55.0	44.4	42.0	41.4
Nationwide	I.C.S.	52.4	44.6	53.4	47.4
	M.S.C.	48.0	42.0	35.6	38.0
	I.C.S.	44.0	44.8	41.4	43.4
Forest City	M.S.C.	41.0	50.2	35.6	45.4
	I.C.S.	47.8	49.6	45.8	46.2
	M.S.C.	55.0	44.4	42.0	41.4
Utica	I.C.S.	47.8	49.6	45.8	46.2
	M.S.C.	55.0	44.4	42.0	41.4
	I.C.S.	52.4	44.6	53.4	47.4
King	M.S.C.	48.0	42.0	35.6	38.0
	I.C.S.	44.0	44.8	41.4	43.4
	M.S.C.	41.0	50.2	35.6	45.4
Dwight Anchor	I.C.S.	47.8	49.6	45.8	46.2
	M.S.C.	55.0	44.4	42.0	41.4
	I.C.S.	52.4	44.6	53.4	47.4
140 Count:	M.S.C.	41.8	48.2	34.0	33.6
	I.C.S.	36.6	46.2	35.6	36.8
	M.S.C.	48.4	49.6	40.8	44.0
Utica	I.C.S.	47.8	49.6	45.8	46.2
	M.S.C.	55.0	44.4	42.0	41.4
	I.C.S.	52.4	44.6	53.4	47.4
King	M.S.C.	48.0	42.0	35.6	38.0
	I.C.S.	44.0	44.8	41.4	43.4
	M.S.C.	41.0	50.2	35.6	45.4
Dwight Anchor	I.C.S.	47.8	49.6	45.8	46.2
	M.S.C.	55.0	44.4	42.0	41.4
	I.C.S.	52.4	44.6	53.4	47.4
180 Count:	M.S.C.	46.4	46.4	39.4	42.8
	I.C.S.	43.8	51.6	43.6	47.6
	M.S.C.	43.4	36.8	32.6	33.2
Duracale	I.C.S.	39.2	37.8	41.6	40.0
	M.S.C.	43.8	40.8	38.2	35.8
	I.C.S.	40.8	45.4	45.2	41.0
Harmony House	M.S.C.	46.4	46.4	39.4	42.8
	I.C.S.	43.8	51.6	43.6	47.6
	M.S.C.	43.4	36.8	32.6	33.2
Golden Dawn	I.C.S.	39.2	37.8	41.6	40.0
	M.S.C.	43.8	40.8	38.2	35.8
	I.C.S.	40.8	45.4	45.2	41.0

* Average of 5 determinations

TABLE 5b
WET BREAKING STRENGTH IN POUNDS*

Brand	Laundry	50	W.	F.	W.	F.	W.	F.	W.	F.
128 Count:										
	M.S.C.	53.8	59.6	46.8	49.4	36.2	41.2	26.2	27.8	
	I.C.S.	52.0	64.0	48.0	49.0	47.2	48.6	36.0	39.4	
	M.S.C.	60.8	50.2	53.0	53.2	44.2	41.4	42.4	38.4	
	I.C.S.	56.4	53.2	53.0	50.8	57.2	45.4	34.2	25.6	
	M.S.C.	51.2	46.6	42.6	41.2	37.2	32.0	22.4	25.8	
	I.C.S.	47.2	46.2	46.0	42.8	41.8	40.8	39.2	36.4	
140 Count:										
	M.S.C.	40.4	43.6	33.0	34.0	30.0	31.4	22.0	28.4	
	I.C.S.	37.4	46.4	34.8	42.0	32.8	41.2	31.6	34.4	
	M.S.C.	59.6	58.6	49.4	51.0	42.8	44.2	34.4	33.0	
	I.C.S.	57.6	56.0	53.2	50.6	47.0	47.8	35.4	34.8	
	M.S.C.	57.6	59.2	50.6	51.8	42.4	45.0	37.6	34.2	
	I.C.S.	60.8	56.2	56.0	49.4	54.2	47.6	45.2	41.0	
180 Count:										
	M.S.C.	54.4	58.0	47.6	56.6	40.8	49.0	37.8	46.8	
	I.C.S.	55.6	63.2	47.4	48.8	45.8	44.0	36.4	41.6	
	M.S.C.	47.0	36.4	42.4	37.2	37.6	37.4	31.8	29.4	
	I.C.S.	42.8	41.8	39.0	34.6	42.8	32.8	23.8	21.6	
	M.S.C.	51.4	45.2	46.2	44.6	35.8	41.4	35.0	36.2	
	I.C.S.	55.8	48.2	51.0	40.8	49.8	38.8	34.4	37.0	

* Average of 5 determinations

PERCENTAGE CHANGE IN BREAKING STRENGTH AFTER LAUNDERING*

Michigan State College Laundry

Number of Launderings		Type 128		Type 140		Type 180	
		Warp	Filling	Warp	Filling	Warp	Filling
50	Dry	+6.7	-0.03	+15.5	+12.4	+32.7	+11.7
	Wet	+4.8	-3.3	+11.6	+0.6	+9.1	+4.9
100	Dry	-3.9	-8.7	-5.9	-10.3	+9.3	+1.01
	Wet	-9.9	-15.4	-12.6	-17.7	-1.8	-10.6
150	Dry	-17.4	-22.1	-21.8	-24.1	-7.3	-1.95
	Wet	-25.6	-33.9	-24.1	-27.2	-16.0	-16.9
200	Dry	-20.8	-33.0	-27.0	-33.8	-17.9	-16.7
	Wet	-43.0	-36.5	-38.5	-41.8	-22.9	-27.5

Ingham County Sanatorium Laundry

50	Dry	+22.1	+1.9	+17.7	+10.8	+22.9	+21.1
	Wet	-1.4	-1.0	+ .03	-1.3	+13.9	- .06
100	Dry	+19.1	+ .30	+7.4	-1.2	+29.2	+16.1
	Wet	-6.8	-12.2	-5.6	-13.6	+1.5	-19.4
150	Dry	+9.1	-7.9	+3.4	-13.7	+17.9	-2.1
	Wet	-7.7	-16.8	-12.4	-16.8	-13.5	-24.8
200	Dry	+1.2	-13.3	-8.8	-10.8	- .33	-5.5
	Wet	-30.1	-36.4	-26.3	-32.7	-30.0	-35.6

*Based on averages by groups.

TABLE 7
BREAKING STRENGTH IN POUNDS AFTER ABRASION*

	Original Unabraded		Original Abraded		M.S.C.Laundry 100		M.S.C.Laundry 200		I.C.S. Laundry 100		I.C.S. Laundry 200	
	W	F	W	F	W	F	W	F	W	F	W	F
<u>128 Count</u>												
Cannon	50.0	50.33	40.8	44.1	37.0	31.8	22.33	27.33	35.0	42.66	32.66	37.66
Nationwide	57.0	40.33	44.3	39.6	33.16	36.5	30.33	30.8	35.66	36.0	31.33	35.16
Forest City	47.5	44.16	39.8	35.1	27.0	30.16	20.33	21.5	33.0	33.5	26.0	32.8
<u>140 Count</u>												
Utica	42.0	48.0	39.0	44.8	21.8	34.66	21.0	17.0	29.5	42.33	22.5	31.16
King	52.66	50.0	46.3	48.0	39.0	40.16	35.66	36.66	39.5	45.33	38.5	40
DwightAnchor	55.0	47.0	48.5	46.0	39.8	39.33	30.66	35.0	45.8	44.8	38.5	42.66
<u>180 Count</u>												
Duracale	44.16	52.83	42.5	42.6	38.33	40.33	28.66	27.66	41.8	37.33	37.5	36.16
HarmonyHouse	43.66	39.0	42.6	28.8	30.33	26.8	26.16	17.5	33.16	26.5	32.66	24.16
GoldenDawn	44.66	45.16	43.0	34.5	29.5	27.33	25.16	23.33	31.5	33.5	30.33	33.0

* Average of six determinations after 200 cycles

TABLE 8

PERCENTAGE LOSS IN BREAKING STRENGTH AFTER ABRASION*

Original abraded	M.S.C. Laundry						I.C.S. Laundry					
	100			200			100			200		
	Warp	Filling	Laundings	Warp	Filling	Laundings	Warp	Filling	Laundings	Warp	Filling	Laundings
Type 128	19.0	5.4	36.9	25.9	53.0	41.4	32.0	16.5	41.6	21.1		
Type 140	10.2	4.2	40.4	21.2	35.4	38.8	23.7	8.5	34.4	21.4		
Type 180	3.1	22.8	25.5	31.4	29.5	50.3	17.4	28.9	23.9	32.1		

* Based on averages by groups after 200 cycles of abrasion.

TABLE 9
WHITENESS RETENTION MEASUREMENTS

	Original	I.C.S. Laundry				M.S.C. Laundry			
		50	100	150	200	50	100	150	200
Dwight Anchor	82.7	78.2	79.2	78.7	79.1	83.9	86.1	85.5	86.5
King		94.5	95.8	95.4	95.7	101.4	104.2	103.4	104.7
Utica	82.1	78.3	79.5	77.8	78.5	83.5	86.2	85.4	85.9
		95.4	96.8	94.8	95.5	101.7	104.9	104.0	104.5
	83.3	81.6	82.5	82.2	81.9	86.4	87.8	87.8	88.3
		98.1	99.1	98.7	98.3	103.7	105.5	105.4	106.0
Golden Dawn	85.2	78.7	79.1	78.5	78.8	84.9	86.4	85.3	86.4
		92.4	93.0	92.2	92.5	99.6	101.3	100.1	101.4
Harmony House	87.3	80.5	80.5	79.6	81.1	85.5	86.8	86.6	84.4
		92.3	92.2	91.3	93.0	98.0	99.5	99.4	96.7
Duracale	85.5	79.5	80.0	78.2	79.9	84.8	86.4	85.8	85.8
		93.0	93.5	91.5	93.4	99.3	101.0	100.3	100.4
Nation Wide	84.2	78.8	79.0	78.8	79.9	83.7	85.8	84.7	86.3
		93.6	93.9	93.5	94.9	99.4	101.9	100.7	102.3
Forest City	85.2	78.0	78.7	78.6	79.0	84.0	86.2	84.6	86.0
		91.7	92.4	92.3	92.8	98.7	101.2	99.5	100.9
Cannon	85.1	78.4	79.2	78.1	79.6	83.4	85.9	85.0	86.2
		92.1	93.0	91.8	93.5	98.0	100.9	99.9	101.3

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