EFFECTS OF OXYGEN BLEACH ON FLAMMABILITY AND TENSILE STRENGTH OF COMMERCIALLY TREATED 100% COTTON FLANNELETTE

by

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INTRODUCTION

According to the National Center for Health Statistics, 517 deaths a year are caused by ignition of clothing. Additional information released from the National Electronic Injury Surveillance System indicates that 15,600 persons annually receive medical treatment for textile related burns; 9,700 involve articles of clothing, including 2,600 specifically in the nightwear area (7). An investigation conducted by the Health, Education and Welfare and Commerce Departments concerning apparel burn injuries concluded that burn injuries involving sleepwear, underwear, dresses, shirts and trousers occurred more frequently to children 5 years of age and younger and to persons 66 years of age and older (16).

In order to eliminate the large number of fabric burn injuries, Congress passed the Flammable Fabrics Act in 1953 to remove highly flammable fabrics from the market. This Act was broadened in 1967 to cover additional areas of textile items (16). On July 29, 1971, a Standard for the Flammability of Children's Sleepwear, (DOC FF 3-71), was adopted and went into effect to cover children's sleepwear sizes 0-6X. Another standard, (DOC FF 5-74), was later adopted which covered children's sleepwear from sizes 7 through 14 (8).

The standards for children's sleepwear have caused the textile industry many problems in developing and testing flame retardant fibers, fabrics, and finishes. Fabrics to be tested must maintain their flame retardant properties through 50 launderings and dryings and pass the vertical flame test for char length and residual flame time according to DOC FF 3-71 and DOC FF 5-74 standards.

Fabric flammability appears to be affected by several laundering variables. Pacheoco and Carfagno (16) found that fabrics laundered with phosphate-based detergents retain their flame retardant properties better than fabrics laundered with citrate-based or carbonate-based detergents. Water hardness also had a detrimental effect on flame retardancy by LeBlanc and LeBlanc (14). They noted that laundering with soap in hard water had a harmful effect on the fire retardancy of both treated cotton and inherently flame retardant synthetic fabrics.

Laundry additives such as fabric softeners and chlorine bleach have been proven to have a detrimental effect on flame retardant finishes. Simpson and Silvernale (19) found that softeners applied to the fabric during the wash phase of the laundering cycle caused failures in the vertical flame test and reduced oxygen-index values. Research conducted by Joseph and Bogle (9) discovered that flame retardant finished fabrics failed the vertical flame test at 30 launderings with the use of chlorine bleach.

Despite this fact a recent survey conducted by the Clorox Company showed that bleach is used in 26% of all washloads containing children's sleepwear (22). Bleach is used to aid detergents in the removal of soils and stains, particularly protein soils. Bleach is also used as a disinfectant against bacteria and viruses (6).

The most popular bleach used in household cleaning today is liquid chlorine bleach. It makes up about 80% of the total bleach market (4). However, dry non-chlorine bleach is gaining widespread popularity, making up the remaining 20% of the bleach market (4).

Dry non-chlorine bleaches, also known as oxygen bleaches, have some specific advantages over liquid chloring bleach. These oxygen bleaches are generally safe on most fibers, fabrics, dyes, and finishes and there is no yellowing of chlorine-retentive fabrics (4).

Recent research conducted by the Clorox Company (22) has proven that its dry non-chloring bleach can have a detrimental effect on flame retardant finished 100% cotton fabrics. Their results showed a failure of the vertical flame test with the use of dry non-chlorine bleach as a laundry additive.

Tensile strength is also an important aspect in evaluating the quality of a textile material. Tensile strength contributes to fabric durability by predicting resistance to damage by pulling or similar forces. Thus consideration of the effect of laundering and bleach on the tensile strength of children's sleepwear is important in assessing the wearability of the garment.

Purpose of Study

Laundry additives such as fabric softeners and bleaches have been shown (9,19) to affect flame retardant characteristics of several fabrics. This study was undertaken to investigate the effect of oxygen bleach on the flammability of 100% cotton fabric treated with THPOH/NH_3 flame retardant finish. It also investigated the interactions of the flame retardant finish, oxygen bleach, and launderings on the tensile strength and percent elongation of the fabrics.

Objectives

This study was undertaken to investigate the following objectives:

1. To determine the effect of a perborate based oxygen bleach on the flame retardancy of a 100% cotton fabric treated with a $THPOH/NH_3$ flame retardant finish (i.e. meeting Federal flammability standard DOC FF 3-71).
2. To determine the effect of a $THPOH/NH_3$ flame retardant finish on the tensile strength and percent elongation of 100% cotton fabric after 0, 10, 20, 30, 40, 50 launderings.
3. To determine the effect of a perborate based oxygen bleach on the tensile strength and percent elongation of untreated 100% cotton fabric and 100% cotton fabric treated with a $THPOH/NH_3$ flame retardant finish after 0, 10, 20, 30, 40, 50 launderings.
4. To determine the effect of 0, 10, 20, 30, 40, 50 launderings on the tensile strength and percent elongation of untreated 100% cotton fabric and 100% cotton fabric treated with a $THPOH/NH_3$ flame retardant finish.

Hypotheses

The following hypotheses were established for this study to determine the significant differences among flammability, tensile strength, and percent elongation.

1. There will be no significant difference in the flame retardancy of the fabrics laundered with detergent and oxygen bleach and those laundered with detergent alone (i.e. ability to meet Federal flammability standard DOC FF 3-71).
2. There will be no significant difference in the tensile strength or in the percent elongation between the 100% cotton fabric finished with THPOH/NH_3 flame retardant finish and the untreated 100% cotton fabric.
3. There will be no significant difference in the tensile strength or in the percent elongation of the fabrics laundered with detergent and oxygen bleach and those laundered with detergent alone.
4. There will be no significant differences among launderings on the tensile strength or on the percent elongation of untreated 100% cotton fabric and 100% cotton fabric treated with THPOH/NH_3 flame retardant finish.

Definition of Terms

The following definitions are cited according to their source.

1. Afterglow - the continuation of glowing of parts of a specimen after flaming has ceased (20).
2. Char length - the distance from the original lower edge of the specimen exposed to the flame to the end of the tear or void in the charred, burned, or damaged area (20).
3. Residual Flame Time - the time from removal of the burner from the specimen to the final extinction of molten material or other fragments flaming on the base of the cabinet (20).
4. Children's sleepwear - any product of wearing apparel up to and including size 6X, such as nightgowns, pajamas, or similar related items, such as robes, intended to be worn primarily for sleeping. Diapers and underwear are excluded from this definition (20).
5. Elongation - the increase in length of a specimen during a tensile test expressed in units of length, for example, centimeters, inches, etc. (1).
6. Percent Elongation - the increase in length of a specimen expressed as a percentage of nominal gage length (1).
7. Tensile Strength - the maximum tensile stress expressed in force per unit cross-sectional area of the unstrained specimen, for example, kilograms per square milimeter, pounds per square inch (1).

REVIEW OF LITERATURE

Burns caused by the ignition of clothing take an estimated 517 deaths a year. An additional 15,600 persons annually receive medical treatment for textile related burns (7). The National Electronic Injury Surveilance System estimated that 158 sleepwear-related injuries (age less that 15) occurred during the fiscal year ending in 1975 (12).

In an effort to protect people from accidental burns, which are expensive and difficult to treat, higher performance standards for apparel fabrics are being required by legislation. Flame retardant finishes are receiving great attention by the textile industry at the present time. The greatest concern is over the flammability of cotton since it is one of the major fibers used to produce civilian, military, and household items (5).

Flammable Fabrics Acts and Flame Retardants

The first durable flame retardant for cotton textiles was invented by William Henry Perkins in 1902 (5). At that time, the largest manufacturer of cotton flannelette persuaded Perkins to conduct flame retardant research because of the large number of accidental burns to children. The manufacturer was afraid these fatalities would cause the sale of this material to be prohibited. Cotton flannelette was popular in those days because it was cheap and shrink resistant. It was used for children's clothing, especially in the homes of the poor. The fabric was highly flammable because of its nap (5).

Perkins realized that a flame retardant must have certain qualities to be successful. 1.) The flame retardant should not effect the hand or durability of the fabric. 2.) The colors or design dyed, printed or woven in the fabric should not be affected. 3.) The fire retardant could not be poisonous or cause skin irritation. 4.) It had to be permanent, it should not be removed after 50 washings. 5.) And finally, the process had to be easy to apply and cheap (5). Many of these requirements for flame retardants still remain in effect today. For example, the Federal flammability standard requires that fabric to pass testing after 50 laundering cycles.

A successful process called NON FLAM was developed by Perkins that added about two cents a yard to the cost of the fabric. Later, research showed that it was not fast to severe washing and that it caused tendering on exposure to light (5).

In 1945, a large number of fatalities occurred when small boys wearing play clothes of "cowboy chaps", made of a highly flammable brushed rayon pile fabric, were burned. Other tragedies took place in 1951 with the use of brushed rayon "torch sweaters". The first Flammable Fabrics Act was passed in 1953 to eliminate these highly flammable fabrics (5).

This Act was expanded in 1967 to cover a wider range of apparel and home furnishings, to allow the Secretary of Commerce to issue a new or revised standard, and to provide for research into flame injuries, flammability of fabrics and the development of improved testing methods. The Department of Commerce found that burn injuries involving sleepwear, underwear, dresses, shirts and trousers occurred more frequently to children 5 years of age and younger and to persons 66 years of age and older (16).

The Standard for the Flammability of Children's Sleepwear, DOC FF 3-71, for children's sleepwear sizes 0-6X was issued by the Department of Commerce in 1972, and became effective on July 29, 1973 (16). The Consumer Product Safety Commission inherited the Flammable Fabric Acts from the Department of Commerce and began operation on May 14, 1973. In 1974, the Consumer Product Safety Commission wanted to develop a new standard for children's sleepwear sizes 7-14. The Standard for the Flammability of Children's Sleepwear Sizes 7 through 14, DOC FF 5-74, went into affect May 1, 1975 (15).

Many flame retardant finishes were developed and tested for cotton and synthetic fabrics over the past several years. Presently, there are 13 durable flame retardant finishes for cotton. Of these 13, only three of them: Pyrovatex CP, Fyrol 76, and $THPOH/NH_3$ are used in the commercial treatment of children's sleepwear (5).

The $THPOH/NH_3$ process for producing durable flame retardant cotton fabrics was developed by George L. Drake, Jr. in 1967 (5). The $THPOH/NH_3$ finish is formed from tetrakis(hydroxymethyl)phosphonium hydroxide (THPOH) and is applied as an aqueous solution of THPOH followed by an ammonia gas cure (13). This finish is mainly suitable for lightweight fabrics such as sleepwear. Drake explains that with the finish, "a highly insoluble polymer forms inside the fiber without crosslinking the cotton, therefore the hand remains essentially unchanged and strength is unaffected." (5). In 1975, over 8 million yards of fabric for children's sleepwear were processed using this finish. This process can also be used on knit fabrics that are napped after treatment (5).

Laundry Detergents and Flammability

Home laundry care can affect the flammability of a textile product in the following ways: 1.) "Reduction or removal of flame resistant finishes as a result of chemical reaction to a laundry product. 2.) Build-up of minerals such as calcium carbonate or fats on the fabric surface as a result of water hardness, washing agent, or make up of the wash load. 3.)Failure to remove soils, such as skin oils, greases and various particulate matter which may burn." (22)

It has been known for a long time that flame retardant cotton fabrics lose their fire retardance when laundered with soap in hard water (14). These soap residues can be removed by laundering in high phosphate detergents or by the addition of a water softening agent to low phosphate detergents (16).

Carbonate-based detergents were also found to have a detrimental effect on flame retardancy as compared to phosphate-based detergents. Failure occurred at 25 launderings due to insoluble calcium deposits. It was found that flame retardant properties could be restored to these fabrics after laundering in a phosphate-based detergent (16).

Bleaches

Bleach is used to aid detergents in the removal of soils and stains. Failure to remove soils, such as skin oils and greases, may cause loss of flame retardancy. Inadequate cleaning has been shown to cause reduced flame retardant properties on 17% of a garment sampling secured from consumers. Washing in hot water with detergent and liquid chlorine bleach restored the flame retardant properties and cleanliness of the garments (22).

Children's sleepwear is subject to many food and other stains. A recent survey showed that bleach is used in 26% of all washloads containing children's sleepwear. Bleach is used in 28% of all washloads containing adult sleepwear and in 22% of all loads containing children's apparel. The study showed that all types of bleach are used because of superior ability to remove stains, particularly protein soils such as human body soils. Bleaches are also used because they are effective disinfectant and deordorizing agents (22).

The three main types of laundry bleach commercially available are: 1.)liquid chlorine, 2.) dry or powdered chlorine, 3.) dry non-chlorine bleach or oxygen bleach. A liquid non-chlorine is also available.

The most common and widely used bleach is sodium hypochlorite or liquid chlorine bleach. It makes up about 80% of the total bleach market (4). Liquid chlorine bleach has been shown to be detrimental to flame retardant finished fabrics. When chlorine bleach was used in previous research failure of the vertical flame test occurred at 30 launderings (9). For this reason care labels for flame retardant sleepwear carry the warning "DO NOT USE BLEACH" (9).

Dry chlorine bleach is safer to handle than the liquid because the chlorine is not released until the powder begins to dissolve in water. When properly formulated, this bleach can come close to liquid chlorine bleach in performance. However, damage to fabrics may result if some of the powder is trapped in the folds of the fabric and only partially dissolved (21).

Dry non-chlorine bleach is gaining widespread popularity. After liquid chlorine bleach, these dry oxygen bleaches make up the next largest and fastest growing segment of the bleach market. These oxygen bleaches are generally safe on all fibers, fabrics, dyes, and finishes and there is no yellowing of chlorine-retentive fabrics (4).

The most widely used compounds for dry oxygen bleaches are the sodium perborates. These bleaches also contain sodium carbonate which provides additional alkalinity allowing the perborate to function more effectively (4). The sodium perborate based oxygen bleach is totally effective only in high temperature water (160°F) and at washing cycles of 10 to 15 minutes. As the water temperature decreases so does the effectiveness of this type of bleach (2).

Another form of non-chlorine bleach is the liquid oxygen bleach or hydrogen peroxide. This type of bleach is now appearing with new emphasis in the laundry additive market. These products also utilize hydrogen peroxide as their active oxidizing agent but their liquid form does not allow the addition of alkaline builkers so they do not perform as effectively as dry oxygen bleaches (2).

Very little research has been done on the effects of oxygen bleaches on flame retardant properties. The Clorox Company completed one study to determine the effect of its dry non-chlorine bleach. It was found that oxygen bleach can be damaging to all commercial flame retardant cotton finishes (22). Presently the Clorox Company is marketing its dry bleach, Clorox II, with the cautionary warning that "repeated use on 100% cotton flame retardant sleepwear may cause loss of flame retardancy." (10).

The Consumer Product Safety Commission has investigated burn injuries involving children wearing flame-resistant sleepwear. Burn injuries covered no more that 10% of the body surface when children were wearing flame retardant sleepwear. Children involved in similar accidents with non flame-resistant sleepwear sustained much more severe injuries (12). Continued research needs to be conducted concerning the flammability of fabrics and the effects laundry additives have on flame retardant properties.

PROCEDURES

This research investigated the effect of oxygen bleach on the flammability of 100% cotton fabric treated with THPOH/NH_3 flame retardant finish. The interactions of the flame retardant finish, oxygen bleach, and launderings upon the tensile strength and percent elongation of the fabrics were also examined.

The fabrics used were 100% cotton flannelette provided by M. Lowenstein and Sons, Inc., Lyman, South Carolina. The flame retardant treated cotton flannelette was finished by the Hooker #5 process which is one of the THPOH/NH_3 type finishes. Both the non flame retardant treated cotton flannelette and the THPOH/NH_3 treated cotton flannelette were seconds in terms of print or appearance only.

The fabric length, width, weight, and warp and filling count were determined according to ASTM D 1910 - 64 (Reapproved 1975).

Laundering Plan

For each fabric, eleven samples were cut 35.6 x 83.8 centimeters (cm). Each of these eleven samples provided five specimens (8.9 x 25.4 cm) in the warp direction for the vertical flame test and five warpwise specimens (2.54 x 15.24 cm) for determination of strength and elongation. One sample of each fabric was not laundered, this provided the control group for the various tests. The remaining samples were laundered according to the American Association of Textile Chemists and Colorists (AATCC) Test Method, 124, IIIb, 1975.

The samples were laundered in a Sears Kenmore Model washing machine with a fourteen minute hot ($60 \pm 3^{\circ}C$) wash and a warm rinse and then dried in a Sears Kenmore vented dryer for thirty minutes at a "normal" setting. Exhaust temperatures of the dryer were maintained from 60 to 71°C.

The detergent used was AATCC Standard Detergent 124. The oxygen bleach used was a commercially available product (Clorox II) which contained sodium perborate in combination with sodium carbonate, a nonionic surfactant, fabric whiteners, and perfumes.

The manufacturer's recommendations concerning the quantity and addition time of the selected oxygen bleach was followed in establishing the washing procedure used in this study.

Five samples (35.6 x 83.8 cm) of both the flame retardant treated fabric and the non flame retardant treated fabric plus enough dummy pieces to make a maximum four pound load were placed in the washing machine. The washer was filled and 90 grams of detergent were added. Approximately one minute after washer agitation began one half cup oxygen bleach was added. The washing proceeded automatically through the final spin cycle.

Two samples (35.6 x 83.8 cm), one untreated and one treated with $THPOH/NH_3$ flame retardant finish were randomly removed at 10, 20, 30, 40, and 50 launderings. The same laundering plan was followed for those samples to be laundered with out bleach, omitting the addition of the oxygen bleach.

Repetition of this procedure at a separate time provided the second replication for the statistical analysis.

Vertical Flame Test

The samples were cut into 8.9 x 25.4 cm specimens for the vertical flame test. These specimens were conditioned in the standard atmosphere for testing of 70°F and 65 percent relative humidity. They were then mounted on specimen holders consisting of two U-shaped steel plates designed to allow the specimen to be suspended in a vertical position and to prevent curling of the specimen when the flame was applied.

After mounting, the specimens were placed in a forced circulation drying oven maintained at 105 $\pm$ 2.8°C to remove all moisture. The specimens remained in the oven for thirty minutes and were then transferred to an air-tight, moisture-tight dessicator where they cooled for not less than thirty but not more than sixty minutes.

After cooling, the specimens were tested by the vertical flame method in a test chamber specified by the DOC FF 3-71 standard. The specimens were suspended in the cabinet and subjected to the flame according to the specified test method.

Tensile Strength and Elongation

The tensile strength and elongation of the test fabrics were evaluated using ASTM D 1682 - 64 (Reapproved 1975). Tensile strength and elongation were tested in the warp direction only using the One Inch Cut Strip Method (specimen size 2.54 x 15.24 cm). The instrument used for testing was the Scott CRE (constant-rate-of-extension) Tester. With this machine the rate of increase of specimen length is uniform with time.

The following formula was used to calculate tensile strength:

Final measurement x WR = strength in kg

Final measurement = measurement, in units, determined from the chart of the CRE

WR = the number of kilograms equalling 1 unit for the working range that was used in the operation of the CRE

The percent elongation was calculated using the following formula:

$$\frac{\text{Measurement on chart}}{\text{Original Measurement (jaw separation)} \times \frac{\text{chart speed}}{\text{crosshead speed}}} \times 100 = \text{percent elongation}$$

Measurement on chart = the measurement, in units, determined from the chart of the CRE. One division on the chart equals .25 cm.

Original Measurement = the distance between the clamps (jaw separation) at the start of the test. Usually 3 $\pm$ 0.05 inches.

Chart speed = the speed at which the chart moved, in centimeters/min.

Crosshead speed = the speed at which the crosshead moved, in centimeters/min.

Statistical analyses of the tensile strengths and the percent elongations were performed using analysis of variance. Differences among means that were at .01 and .05 levels of significance were noted.

DISCUSSION OF RESULTS

Residual Flame Time and Char Length

All of the specimens treated with THPOH/NH_3 flame retardant finish passed the Federal flammability standard. When laundered with the selected perborate based oxygen bleach, none of the flame retardant specimens had a residual flame time greater than .1 seconds. Char length appeared to increase slightly with the use of oxygen bleach. Char length of the flame retardant finished fabric increased from 4.9 centimeters (cm) at zero launderings to 5.5 cm at 50 launderings with oxygen bleach. Specimens not laundered with oxygen bleach had a char length of 4.8 cm after 50 launderings. This small increase has very little significance when all specimens pass the Federal flammability standard. The THPOH/NH_3 flame retardant finish inhibited afterglowing of the specimens when the flame was removed.

The untreated 100% cotton specimens all failed the Federal flammability standard. Residual flame time was greater than 10 seconds on all specimens. The entire specimen ignited and burned leaving only black ashes. After the flame was extinguished the untreated fabrics exhibited an afterglow.

Physical characteristics of the THPOH/NH_3 flame retardant finish and untreated fabrics are shown in Table 1.

Tensile Strength

The tensile strength of the fabrics were dependent upon the interaction of the variables of bleach, finish, and launderings. Analysis of variance and significance levels are presented in Table 2.

Table 1. PHYSICAL CHARACTERISTICS OF FABRICS

	$THPOH/NH_3$ flame retardant finish	Untreated
Method of Construction	plain weave	plain weave
Fiber Content	100% cotton	100% cotton
Length	11.11 yards	11.50 yards
Width	46.06 inches	41.70 inches
Weight	4.87 oz/yd^2	3.95 oz/yd^2
Warp Count	17.80/cm	19.60/cm
Filling Count	17.60/cm	17.00/cm

Table 2. ANALYSIS OF VARIANCE OF TENSILE STRENGTH

FIRST ORDER INTERACTIONS			
Source of variation	df	F ratio	Significance level
Bleach	1	25.95	.01
Finish	1	581.99	.01
Launderings	4	9.44	.01
Replications	1	0.13	NS
SECOND ORDER INTERACTIONS			
Bleach by Finish	1	1.58	NS
Finish by Launderings	4	3.20	.05
Bleach by Launderings	4	5.25	.01
THIRD ORDER INTERACTIONS			
Bleach by Finish by Launderings	4	4.62	.01

NS denotes not significant.

The untreated cotton fabric had a slightly lower tensile strength before laundering than the flame retardant finished fabric. The mean tensile strength of the untreated cotton fabric before launderings was 15.8 kilograms (kg) as compared with 18.7 kg of the $THPOH/NH_3$ flame retardant finished fabric. The flame retardant finish appeared to exhibit a difference (i.e. 2.9 kg) in the tensile strength before laundering.

The effects of the laundering and bleach variables on the mean tensile strength of the untreated cotton fabric and the cotton fabric treated with $THPOH/NH_3$ flame retardant finish are shown in Table 3. Table 3 also shows the mean percent strength loss of both fabrics with and without bleach.

Table 3. MEAN TENSILE STRENGTH OF $THPOH/NH_3$ FINISHED FABRIC AND UNTREATED COTTON FABRIC.

MEAN TENSILE STRENGTH OF $THPOH/NH_3$ FINISHED FABRIC

Before laundering 18.7 kg

	Launderings 10	20	30	40	50		Means
with oxygen bleach	17.6kg	15.5kg	15.7kg	15.5kg	14.8kg	=	15.8 kg
% strength loss	5.9%	17.1%	16.0%	17.1%	20.8%		15.5%
without bleach	16.6kg	16.8kg	16.0kg	16.8kg	17.2kg	=	16.7 kg
% strength loss	11.2%	10.2%	14.4%	10.2%	8.0%		10.7%

MEAN TENSILE STRENGTH OF UNTREATED COTTON FABRIC

Before laundering 15.8 kg

	Launderings 10	20	30	40	50		Means
with oxygen bleach	13.1kg	13.7kg	12.1kg	12.9kg	11.6kg	=	12.7 kg
% strength loss	17.1%	13.3%	23.4%	18.4%	26.6%		19.6%
without bleach	13.6kg	13.6kg	13.1kg	12.9kg	12.7kg	=	13.2 kg
% strength loss	13.9%	13.9%	17.1%	18.4%	19.6%		16.5%

There appears to be a slight weakening effect occurring with increased launderings. Comparison of the original values of tensile strength before laundering with the mean values of launderings without bleach gives this indication. This comparison shows a difference of 2.0 kg (10.7%) in the flame retardant finished fabric and a difference of 2.6 kg (16.5%) in the untreated cotton fabric.

As shown, the untreated cotton fabric exhibits a greater decrease in tensile strength as launderings increase than the flame retardant finished fabric. Statistically, the second order interaction of finish by launderings was significant at the .05 level of significance. However, when comparing the mean tensile strengths of the flame retardant treated fabric at 30, 40, and 50 launderings without bleach a slight increase in tensile strength actually occurred as the launderings progressed. Thus, this interaction is not as significant as indicated.

The perborate based oxygen bleach decreased the tensile strength of the untreated cotton fabric and the cotton fabric treated with $THPOH/NH_3$ flame retardant finish. A comparison of the original values of tensile strength before laundering with the mean values of launderings with oxygen bleach indicates a difference of 2.9 kg (15.5%) with the flame retardant finished fabric and a difference of 3.1 kg (19.6%) with the untreated fabric. A much larger difference can be seen when comparing the original values before laundering to the mean values at 50 launderings. This comparison shows a difference of 3.9 kg (20.8%) with the flame retardant finished fabric and a 4.2 kg (26.6%) difference with the untreated cotton fabric. The perborate based oxygen bleach had no greater an effect on the tensile strength of the flame retardant finished fabric than on the untreated fabric.

When comparing the launderings with and without oxygen bleach a slight diminishing effect occurred on the tensile strength with the addition of oxygen bleach. A comparison of mean values with and without oxygen bleach indicated a difference of 0.9 kg (15.5% with bleach to 10.7% without bleach) with the flame retardant treated fabric and a difference of 0.5 kg (19.6% with bleach to 16.5% without bleach) with the untreated fabric. A much larger difference was seen when the mean values of the fabric treated with and without oxygen at 50 launderings were compared. This comparison showed a difference of 2.4 kg (20.8% with bleach to 8.0% without bleach) with the flame retardant finished fabric and a difference of 1.1 kg (26.6% with bleach to 19.6% without bleach) with the untreated cotton fabric. A slightly greater decrease in tensile strength was observed when the $THPOH/NH_3$ flame retardant finished fabrics laundered with and without oxygen bleach were compared to the untreated cotton fabric.

Percent Elongation

The percent elongation of the fabrics was dependent upon the interaction of the variables of bleach, finish, and launderings. Analysis of variance and significance levels are presented in Table 4.

Before laundering, the untreated fabric had a slightly lower percent elongation (9.5%) than the flame retardant finished fabric (10.9%). A significant difference in the percent elongation was observed.

Table 5 shows the effects of the laundering and bleach variables on the mean percent elongation of the untreated cotton fabric and the cotton fabric treated with $THPOH/NH_3$ flame retardant finish.

Table 4. ANALYSIS OF VARIANCE OF PERCENT ELONGATION

Source of variation	df	F ratio	Significance level
FIRST ORDER INTERACTIONS			
Bleach	1	5.28	.05
Finish	1	81.51	.01
Launderings	4	9.01	.01
Replications	1	7.46	.01
SECOND ORDER INTERACTIONS			
Bleach by Finish	1	0.56	NS
Finish by Launderings	4	1.46	NS
Bleach by Launderings	4	6.21	.01
THIRD ORDER INTERACTIONS			
Bleach by Finish by Launderings	4	1.67	NS

NS denotes not significant.

Table 5. MEAN PERCENT ELONGATION OF $THPOH/NH_3$ FINISHED FABRIC AND UNTREATED COTTON FABRIC.

MEAN PERCENT ELONGATION OF $THPOH/NH_3$ FINISHED FABRIC

Before laundering 10.9%

	Launderings 10	20	30	40	50		Means
with oxygen bleach	11.6%	11.6%	10.6%	10.4%	10.1%	=	10.9%
without bleach	10.5%	12.5%	10.6%	10.9%	11.0%	=	11.1%

MEAN PERCENT ELONGATION OF UNTREATED COTTON FABRIC

Before laundering 9.5%

	Launderings 10	20	30	40	50		Means
with oxygen bleach	12.9%	11.9%	12.1%	11.8%	12.2%	=	12.2%
without bleach	12.2%	14.2%	13.1%	11.6%	12.4%	=	12.7%

A slight increasing effect on the percent elongation occurred with increased launderings. The flame retardant treated fabric increased from 10.9% elongation before laundering to 11.1% after launderings. The untreated fabrics increased from 9.5% elongation before laundering to 12.7% after launderings. As can be seen in Table 5, the untreated cotton fabric produced a greater increase in percent elongation with launderings than did the flame retardant finished fabric.

In comparing the mean percent elongation of the flame retardant finished fabric and untreated fabric at the various laundering levels a large fluctuation in values was apparent.

The perborate based oxygen bleach had little effect on the percent elongation of the flame retardant finished fabric. A comparison of the original value before launderings (10.9%) with the mean value of launderings with oxygen bleach (10.9%) showed no difference. However, the original value before laundering compared to the mean percent elongation at 30, 40, and 50 launderings showed a slight decrease in percent elongation. The decreasing effect continued to occur as the launderings increased.

The oxygen bleach exhibited a much greater effect on the untreated cotton fabric than the flame retardant finished fabric. There was an increase in percent elongation with the oxygen bleach on the untreated cotton fabric from 9.5% before laundering to 12.2% after laundering.

A slight decrease from 11.1% elongation to 10.9% can be seen in Table 5 on the mean elongation values with the addition of oxygen bleach to the launderings on the $THPOH/NH_3$ flame retardant finished fabric. The untreated cotton fabric also showed a slight decrease in the mean values with the addition of oxygen bleach from 12.7% elongation to 12.2%.

CONCLUSIONS AND SUMMARY

The 100% cotton fabric treated with a $THPOH/NH_3$ flame retardant finish met the Federal flammability standard DOC FF 3-71 when laundered with the commercially available perborate based oxygen bleach selected.

Data from the study showed that the tensile strength and elongation of fabrics were influenced by the type of finish used. Tensile strength and percent elongation increased with the use of the $THPOH/NH_3$ flame retardant finish.

Tensile strength decreased as launderings increased. The untreated cotton fabric showed a greater decrease in strength as launderings increased. The perborate based oxygen bleach also had a decreasing effect on the tensile strength of both the untreated cotton fabric and the flame retardant finished cotton fabric. The $THPOH/NH_3$ flame retardant finished fabric showed a slightly greater decrease in tensile strength laundering with and without oxygen bleach compared with the untreated cotton fabric.

Percent elongation increased as launderings increased. A much greater increase in percent elongation was present in the untreated cotton fabric as launderings increased. The oxygen bleach had no effect on the percent elongation of the flame retardant finished fabric. However, the oxygen bleach caused an increase in percent elongation on the untreated cotton fabric.

REJECTED HYPOTHESES

The following hypotheses were rejected:

1. There will be no significant difference in the tensile strength

or in the percent elongation between the 100% cotton fabric finished with $THPOH/NH_3$ flame retardant finish and the untreated 100% cotton fabric.

2. There will be no significant differences among launderings on the tensile strength or on the percent elongation of untreated 100% cotton fabric and 100% cotton fabric treated with $THPOH/NH_3$ flame retardant finish.

3. There will be no significant difference in the tensile strength of the fabrics laundered with detergent and oxygen bleach and those laundered with detergent alone.

4. There will be no significant difference on the percent elongation of the untreated cotton fabric laundered with detergent and oxygen bleach and that laundered with detergent alone.

ACCEPTED HYPOTHESES

The following hypotheses were accepted:

1. There will be no significant difference in the flame retardancy of the fabrics laundered with detergent and oxygen bleach and those laundered with detergent alone.

2. There will be no significant difference on percent elongation with the use of oxygen bleach on the $THPOH/NH_3$ flame retardant finished fabric.

RECOMMENDATIONS FOR FURTHER STUDY

1. Additional physical tests should be performed to determine the effect of oxygen bleach in relation to tear strength and abrasion resistance.

2. This study should be expanded to include the effect of oxygen bleach on colorfastness and the effects on fiber morphology as seen in scanning electron microscopy (SEM).

3. This particular study should be repeated using a different type of oxygen bleach or laundry additive.

4. This study could be repeated with different flame retardant finishes for 100% cotton fabric, a cotton/polyester blend fabric, and inherently flame retardant fibers.

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EFFECTS OF OXYGEN BLEACH ON FLAMMABILITY AND
TENSILE STRENGTH OF COMMERCIALLY TREATED 100% COTTON FLANNELETTE

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The effects of oxygen bleach were studied on the flammability, tensile strength, and percent elongation of a 100% cotton fabric treated with $THPOH/NH_3$ flame retardant finish and an untreated 100% cotton fabric. The oxygen bleach used was a commercially available product (Clorox II) which contains sodium perborate as the main ingredient.

The specimens were subjected to the vertical flame test as described in the Standard for the Flammability of Children's Sleepwear, DOC FF 3-71. Tensile strength and percent elongation were tested by using a constant-rate-of-extension tensile tester.

All of the specimens treated with $THPOH/NH_3$ flame retardant finish passed the Federal flammability standard. None of the specimens had a residual flame time greater than .1 seconds, a char length greater than 5.5 centimeters or exhibited afterglowing.

Tensile strength and percent elongation are increased initially by the use of the $THPOH/NH_3$ flame retardant finish. Tensile strength decreased as launderings increased. The untreated cotton fabric showed a greater decrease in strength as launderings increased. The oxygen bleach also had a decreasing effect on the tensile strength. The flame retardant finished fabric showed a slightly greater decrease in tensile strength laundering with and without oxygen bleach compared with the untreated cotton fabric.

Percent elongation increased as launderings increased. A much greater increase in percent elongation was present in the untreated cotton fabric as launderings increased. The oxygen bleach caused an increase in percent elongation on the untreated cotton fabric.