THE EFFECT OF PERSPIRATION, ANTIPERSPIRANTS AND ATMOSPHERIC FUMES ON THE COLORFASTNESS OF SELECTED FABRICS

by

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The fading of dyes through chemical reactions with acid substances has been a problem of economic importance to consumers, retailers, drycleaners and textile manufacturers for a number of years. Precautionary measures have been taken by using acid resistant dyes or by inhibiting acid sensitive colors against fading or color change. These measures have lessened the problem of color change to some extent, but colorfastness of dyed fabrics continues to be a subject of considerable research in the textile industry.

This study was a pilot study which will serve as a basis for continued research in the area of colorfastness to perspiration, antiperspirants and atmospheric fumes. The purposes of the study were to test the color sensitivity of selected fabrics to perspiration, antiperspirants and a combination of these two factors, and to determine the effects of the oxides of nitrogen on selected fabrics treated with perspiration and antiperspirants.

The solutions used in the study include:

1. Distilled water
2. Acid perspiration
3. Alkaline perspiration
4. Aluminum sulfate
5. Aluminum chlorohydroxide
6. Aluminum chloride

Laboratory tests were carried out in order to determine the effects of perspiration and antiperspirants on the selected fabrics. The fabrics used were of acetate and non-acetate fiber content. The selected fabrics which had been stained with the test solutions were later exposed to the oxides of nitrogen for one exposure period.

The evaluation of color changes was done subjectively by three judges.

The results of the study show that:

1. The colors in all fabrics maintained excellent resistance to the perspiration solutions.

2. There was more evidence of color change in fabrics which were treated with the antiperspirant solutions and the combinations of perspiration with the antiperspirants.

3. The Class A and Class B dyed acetate fabrics were affected similarly by the stain test solutions.

4. The fabric which was finished with the fugitive inhibitor was more sensitive to the stain test solutions than was the fabric that was finished neutral or the fabric that was finished with the substantive inhibitor.

5. The non-acetate fabrics showed more evidences of color changes than did the acetate fabrics, however this can be attributed to chemical deposits on the non-acetates.

6. The stained areas of the Class B dyed fabrics were more affected by the fumes than were the stained areas on the Class A dyed fabrics.

7. The inhibitors lost their effectiveness when treated with the antiperspirants and with the combinations of both perspiration solutions with the antiperspirants.

8. The stained areas on the Class A dyed fabrics and the non-acetate fabrics were more resistant to the fumes than were the stained areas on the Class B dyed acetate fabrics.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

I. STATEMENT OF THE PROBLEM

Color change in fabrics is a common occurrence, and a problem not of recent origin. One of the chief problems related to color change which concerns the consumer is the effect of chemical substances such as perspiration and antiperspirants on colors applied to fabrics. Another problem is that of the effect of atmospheric contaminants upon colors.

The first section of this study was planned to test the color sensitivity of fabrics to perspiration, antiperspirants and a combination of these two factors. Specific objectives of this section of the study were:

1. To determine the effect of perspiration and antiperspirants on colors in selected acetate fabrics.

2. To determine differences in color sensitivity of selected acetate fabrics treated with fume fading inhibitors and to determine color sensitivity of the same fabrics to which no fume fading inhibitor had been applied.

3. To compare the color sensitivity of the selected acetate fabrics with the color sensitivity of selected non-acetate fabrics.

The second section of the study was planned to determine the effects of an atmospheric contaminant oxides of nitrogen on fabrics treated with perspiration and antiperspirants. The specific objectives for this section of the study were:

1. To determine the effect of fumes on the colors of fabrics treated with perspiration and antiperspirants.

2. To determine differences in color sensitivity of acetate fabrics treated with fume fading inhibitors and the color sensitivity of the same fabrics to which no fume fading inhibitor had been applied.

3. To compare the color sensitivity of the selected acetate fabrics with the color sensitivity of selected non-acetate fabrics.

II. IMPORTANCE OF THE PROBLEM

In an article by Herman B. Goldstein it was pointed out that acetate fabrics are particularly sensitive to color change. With the increasing use of cellulose acetate during the decade of the 1930's, the seriousness of the problems related to color changes in fabrics became apparent. Acetate is extremely susceptible to changes in shade because of the chemical characteristics of the fiber and the dyestuffs used in the manufacture of the fabric.

> . . . when this fiber acetate was dyed with certain classes of dyestuffs, although the dyestuffs in question were considered fast-to-light and other then known deteriorating influences, the dyed fabrics showed marked and unpredictable changes in shade.[1]

Since the recognition of this problem there has been a great amount of publicity regarding changes on dyed acetate fabrics because of fume fading, however according to Johnson:

> . . . colors are sensitive to many common acid substances other than the nitrous oxides present in the air. These include even extremely mild forms of acid perspiration,

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[1]Herman B. Goldstein, "Research Has Solved Acetate's Big Problem Gas Fading," Textiles Forum (April, 1953), 21.

fruit juices and beverages, spot and stain removal chemicals, deodorants, hair preparations and antiperspirants.[2]

Any substance which leaves the fabric in an acid condition tends to accelerate color change. This acid sensitivity of dyes has been very confusing and has caused considerable misunderstanding on the part of the consumer.[3] Discoloration in a fume faded fabric is not necessarily similar to a change in shade caused by perspiration and antiperspirants. It is sometimes difficult to distinguish between the two because the changes are not equally pronounced, nor are they located in the same areas when occurring on a garment. Also color change which is not immediately noticeable may become apparent after drycleaning. This color change does not occur as a result of the chemicals used in the drycleaning process.[4] "It is thought however that the heat of pressing and steam finishing tends to bring out faded areas."[5]

The problem of color sensitivity not only concerns the consumer but also concerns the retailer, the drycleaner and the textile manufacturer. Retailers have suffered losses because of color changes which occur in garments while being displayed or while in storage. Dry cleaners must take precautions when handling fabrics which are subject to color change. The chemicals used in spotting must be carefully selected for

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[2]Albert E. Johnson, "Fabric Behavior in Dry Cleaning: Acid Sensitive Acetate Colors (Third of a Series), Modern Textiles, No. 11 (1952), 63.

[3]Ibid., 64.

[4]Johnson, loc. cit.

[5]Johnson, loc. cit.

each fabric, and the amount of heat used in pressing the garments must be regulated according to color and fabric. Consumers are disappointed when garments change color while hanging in the closet or after dry cleaning. The natural reaction is for the consumer to assume that the retailer has sold poor merchandise or that the drycleaner has used chemicals which have affected the fabric. Neither of these suppositions is correct since the source of the difficulty is concerned with the fiber and the dyestuff used in manufacturing the fabric.[6] The problem of color changes caused by acid substances has been the object of considerable research. Textile manufacturers have delegated to special committees this responsibility of research on color fastness.[7]

The results of outstanding studies related to perspiration, antiperspirants, acid fumes and their effects on fabrics will be reviewed in Chapter II.

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[6] V. S. Salvin, W. D. Paist, W. S. Myles, "Advances In Theoretical and Practical Studies of Gas Fading," American Dyestuff Reporter (May 12, 1952) 297.

[7] Technical Manual of the American Association of Textile Chemists and Colorists, Part I, Vol. XXXVIII (1962), A-8 —A-11.

CHAPTER II

REVIEW OF LITERATURE

The survey of the literature indicated that few studies related to the effects of perspiration and antiperspirants on fabrics have been reported. Those reports which were located related more to the composition of perspiration and antiperspirants and the effect of these factors on physical properties such as strength and serviceability than to the effect on the colors applied to the fabrics.

An attempt has been made in this chapter to include a review of the chemical and biological nature of perspiration and antiperspirants and their effect on fabrics and the colors applied to fabrics.

Extensive literature pertaining to fume fading was available. This included the history of the problem, the development of a standard laboratory test procedure, and current problems associated with the numerous atmospheric contaminants other than the oxides of nitrogen.

I. PERSPIRATION AND ITS EFFECT ON FABRICS

Physiology of Perspiration

Sweat is excreted by an enormous number of glands which are located on the skin surface. Eccrine glands are distributed almost entirely over the whole body, and the apocrine glands are concentrated in a few areas. The eccrine gland, microscopic in size, begins in the lower layer of skin as a coil, and it terminates on the skin surface with a small tubular opening. There are approximately two to three million of these glands in the body. "The function of the eccrine gland, the heat regulator, is to flood the surface of the body with water, which cools the surface by evaporation."[1] These eccrine glands are not always in the active state. The major stimulus for the eccrine gland is heat, however they also react ". . . when the nervous system responds to pain, to fear, to anger or to similar strong emotions."[2]

Apocrine glands secret continuously in small quantities, however the stimulation may be from fear or response to pain. Heat is not a stimulus for the aprocrine gland. "Discharge of the gland contents results in inability to discharge again for a day or so until the gland has had a chance to be refilled."[3]

The third type of skin gland is the sebaceous gland. This gland lubricates the skin with an oily substance known as sebum.[4]

The daily output of perspiration varies greatly depending upon a number of factors. From one pint to three quarts are secreted daily with the larger amounts being produced in the summer and the smaller amounts being produced in the winter. Sweat nerves act upon the sweat glands to cause the secretion, however this action is not entirely dependent on heat. Sweat may be secreted because of ". . . cold, nausea,

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[1]Joseph Kalish, "Deodorants and Antiperspirants," <u>Drug and Cosmetic Industry</u> (August 1959), 175.

[2]<u>Ibid</u>.

[3]<u>Ibid</u>.

[4]________, "Some Basic Facts about Deodorants and Antiperspirants," <u>Consumer Reports</u> (July 1959), 379.

psychic disturbances, as by heat. Perspiration can also be produced by indirect causes such as general heat, muscular exercise and drugs."[5]

More perspiration is produced as a result of heat than by any other cause.

> Up to 33°C the amount of perspiration increases with the temperature under normal atmospheric conditions. Above 33°C, however the amount of perspiration does not increase in proportion with the external temperature, except when the atmosphere humidity increases also, or when the body is covered with highly protective clothing such as heavy woolens or fur.[6]

Biochemistry of Perspiration

Perspiration contains 98 per cent water and 2 per cent dissolved solids. It has an average pH of 4.5 and an average density of 1.006. "Perspiration is composed of organic (ammonium compounds, urea, amino acids, lactic acid, glucose, etc.) and inorganic matter (almost entirely chlorides)."[7] In addition to these materials perspiration contains skin cells and external dirt. There are also traces of creatinine, serin, aromatic oxy-acids, etheral sulphates of phenol and skatol, albumin, vitamins B_1, B_2 and C, and nicotinic acid. Carbon dioxide is also one of the components of perspiration.[8]

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[5] L. C. Barail, "Perspiration -- What Do Textile Men Know About It?" Rayon Textile Monthly (December, 1946), 93.

[6] Ibid.

[7] M. G. DeNavarre, The Chemistry and Manufacture of Cosmetics, (New York: D. Van Norstrand Company, Inc., 1941) 260.

[8] Barail, op. cit., 94.

There are differences in the composition of human perspiration, however the variations are extremely slight. "They consist in + or − changes evaluated in milligrams or even micrograms, a milligram being 1/28,000th of an ounce, and a microgram being 1/28,000,000th of an ounce."[9] These variations in the chemical composition occur as a result of differences in water, food and drug intake. The variations which occur in perspiration concern all of the chemical constituents of perspiration. "The concentration in chlorides, phosphates, and other salts, vary with water intake and physical exertion."[10] Foods and drugs effect the changes in ammonia, urea, uric acid, cholesterol, aromatic oxy-acids, etheral sulphates of phenol and skatol, albumin, creatinine and serin. In addition to these substances, vitamins are also affected by food and drug intake. The vitamins subject to change are thiamin chloride, riboflavin, niacin, pyridoxin, pantothenic acid, biotin, inositol, p-aminobenzoic acid, and ascorbic acid.

> Other minute changes occur whether or not drugs have been taken either orally, or by injections, or externally, and when pathological disturbances have an action on metabolism, for instance sugar in cases of diabetes. Some drugs are eliminated as in sweat, some others undertake chemical changes in the body, but the result is always a change in chemical composition and a difference in odor.[11]

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[9] L. C. Barail, "Effects of Various Kinds of Perspiration on Fabrics," Rayon Textile Monthly (August 1947), 87.

[10] Ibid.

[11] Ibid., 88.

Bacteriology of Perspiration

When perspiration is first secreted it is acid in nature having a pH of 4.5. However, when perspiration omes in contact with the bacteria and fung' on the skin, in the air and on fabrics, bacterial decomposition takes place and an unpleasing odor develops.[12] When bacterial decomposition occurs in perspiration the pH of the solution passe the neutral point and becomes alkaline.[13]

Perspiration Odors

The odors which occur when fresh perspiration decomposes are of endogenous and exogenous causes. The endogenous causes of perspiration odor include: the influence of foods, the influence of drugs and body cleanliness and cleansers. The exogenous causes of perspiration odor include: the influence of weather, the influence of environment, and the influence of wearing apparel.[14]

Effects of Fresh Perspiration on Fabrics

Fresh perspiration, perspiration in which bacterial decomposition has not taken place, has practically no harmful effects on fabrics.

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[12] L. C. Barail, "Perspiration — What Do Textile Men Know About It?" Rayon Textile Monthly (December, 1946), 94.

[13] L. C. Barail, "Perspiration Effects on Fabrics," Rayon Textile Monthly, (September 1947), 112.

[14] L. C. Barail, "Effects of Various Kinds of Perspiration on Fabrics," Rayon Textile Monthly. (August 1947), 88-89.

However, fresh perspiration can cause considerable damage to dyes and finishes. In addition, fresh perspiration can reduce the effectiveness of germicides and fungicides which have relatively high pH values.

Vat dyes, acid dyes, and developed colors are fast to fresh perspiration. Most of the basic dyes and some direct and metallic dyes are subject to discoloration when submitted to fresh perspiration. The discoloration is a result of either a bleeding or staining action. When fresh perspiration comes in contact with a fabric which has been treated with an alkaline finish the finish is precipitated thus producing an irritating, rough fabric surface. Germicides or fungicides, which are alkaline are affected in a similar manner. Those having an acid nature are not affected by fresh perspiration.[15]

Effects of Decomposed Perspiration on Fabrics

Contaminated perspiration, perspiration which has decomposed and which has a high pH value, has a greater destructive action on fabrics than does fresh perspiration.

> . . . Contaminated perspiration reduces the tensile strength of all animal or vegetable fabrics. The reduction of tensile strength varies with the pH of the perspiration. The more alkaline the perspiration the greater the damage. This damage increases with the length of time that the fabric is in contact with the perspiration, and the greater the number of contacts the greater the damage. Reduction of fabric tensile strength because of contaminated perspiration is also dependent on the moisture of the fabric. If the fabric is soaked in perspiration, destruction occurs much more rapidly. The final factor influencing the perspiration effects on tensile strength is the

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[15]L. C. Barail, "Perspiration Effects on Fabrics," Rayon Textile Monthly (September 1947), 112.

cleansing agent which is used when laundering the fabrics. A harsh detergent, having an excess of alkali, will increase perspiration effects on fabrics.[16]

Vat dyes and developed colors are faster to contaminated perspiration than other types of dyes. The basic dyes are subject to discoloration when in contact with perspiration. When in contact with contaminated perspiration the dyes bleed, fade or stain.

Contaminated perspiration has a harmful effect on finishes applied to fabrics. "Among the finishes are included not only finishing oils, sulfonated or not, but such compounds as water-proofing or fire proofing chemicals, fire retardants, germicides and fungicides."[17] Contaminated perspiration reduces the effectiveness of acid finishes by neutralization and precipitation. Alkaline finishes ". . . become diluted and their efficiency decreases because of insufficient concentration."[18]

<u>Methods of Preventing Perspiration Effects on Fabrics</u>

The two methods used to prevent perspiration effects on fabrics are first, to reduce the amount of perspiration produced by the body, and second, to treat the fabric.[19]

The amount of perspiration can be reduced by using antiperspirants. The antiperspirants do not completely eliminate perspiration

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[16] *Ibid.*, 113.

[17] *Ibid.*, 113.

[18] *Ibid.*

[19] *Ibid.*

therefore they do not adequately protect the fabric. Also the chemicals used in the manufacture of these cosmetics, such as aluminum sulfate and aluminum chloride have a damaging effect of their own on fabrics unless the chemicals are properly buffered.[20]

Fabrics can be treated in various ways to resist attack by perspiration. The best and most durable finish can be applied as a last rinse in the mill processing of fabrics.

> The solutions used at the mill are dilutions of strong germicides-fungicides . . . There are germicides-fungicides that would completely protect fabrics by preventing the bacterial decomposition of perspiration and insure such protection after as many as thirty home washings. They are non-toxic, non-irritating to the skin, and do not cause any sensitization. Some are odorless and colorless and very easy to apply at very low cost.[21]

These germicides-fungicides can be used on all types of fabrics. The solutions actually penetrate the fibers, prevent bacterial decomposition of perspiration and make the fibers germicidal and sterile. This is the best protection that can be given to a fabric.[22]

Germicides-fungicides can be also applied at home, at the dry cleaners or at laundries. This treatment outside of the mill is not as effective as that done in mill processing because the fabrics have already lost some of their tensile strength and colorfastness.[23]

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[20] Ibid.

[21] Ibid., 114.

[22] Ibid.

[23] Ibid.

II. ANTIPERSPIRANTS AND THEIR EFFECT ON FABRICS

Development of Deodorants and Antiperspirants

The fact that underarm perspiration is offensive to others was known hundred of years ago. In the past men and women used perfumes and oils to mask the disagreeable perspiration odors, however this first attempt to suppress the perspiration odor did not eliminate the harmful effects of perspiration on fabrics. As the action of perspiration on fabrics became better known an attempt was made to eliminate the odor of sweat by a deodorizing action. "This was the first step in the manufacture of the present type cosmetics which are known as deodorants and antiperspirants. The second step was to prevent the production of sweat."[24]

The two methods of preventing perspiration odor are by either stopping perspiration or by preventing its bacterial decomposition.

> A deodorant preparation is formulated to prevent the development of odor in the originally odorless sweat; it will not reduce the volume of perspiration. Reduction in the flow of perspiration is the intent of antiperspirants, and these preparations are also deodorants. Neither is it intended as a substitute for frequent bathing.[25]

Approximately 90 per cent of the women in the United States use deodorants and antiperspirants and only 60 per cent of the men in the

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[24] L. C. Barail, "Perspiration, Part II, What Do Textile Men Know About It?" Rayon Textile Monthly (February 1947), 83.

[25] J. Kalish, "Deodorants and Antiperspirants," Drug and Cosmetic Industry (August, 1959), 175.

United States use these preparations for checking perspiration odors. Results of a survey in 1959 prompted a speculation that ". . . 60 per cent of the preparations sold are probably antiperspirants and 40 per cent deodorants, 32 per cent are creams, 32 per cent are roll-on packages, 20 per cent are liquids (including lotions and squeeze bottles), and 16 per cent are sticks."[26]

Formulation of Deodorants

The primary ingredient of a deodorant is antibacterial in order to prevent bacterial decomposition of perspiration. The most commonly used antibacterial agents are: hexachlorophene, bithionol, trichlorocarbanilide, and tetramethylthiuram disulfide.

> These have been particularly effective in cake soaps where requirements are somewhat different from those for cosmetic preparations. In deodorant cake soaps, the antibacterial must be active in the presence of the alkaline soap and also substantive to the skin. This will assure the gradual accumulation of active concentrations of antibacterial agent on the skin.[27]

Other substances which serve as effective antibacterials and anti-infectives are tyrothricin, neomycin, and chlortetracycline. When these particular substances are used in deodorants problems arise. They may cause a sensitization reaction or ". . . the development of resistant bacteria might be encouraged."[28] Ion exhange resins are the third type of substances found to be effective for use in deodorants.

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[26] Ibid., 174.

[27] Ibid., 175-265.

[28] Ibid.

> They function as a mixture of anionic and cationic resins, to pick up and hold tightly all of the acidic or basic odorous constituents of sweat by a combination of chemical action and absorption.[29]

According to an article in the July 1959 issue of Consumer Reports, deodorants containing an antiseptic have longer lasting protection than do deodorant soaps containing antiseptics, because more of the deodorant chemical remains on the skin. In the same article it was reported:

> ". . . neomycin and other antibiotics, in skin preparations, could effectively control underarm odor by inhibiting bacterial growth. Although effective, such preparations could induce allergic reactions in some individuals or encourage the development of strains of microorganisms resistant to antibiotics.[30]

Formulation of Antiperspirants

The astringent substances used in antiperspirants to reduce the flow of perspiration are various aluminum salts and other polyvalent metallic ions.

> Their mode of action is not entirely clear, but may be related to their power to swell and coagulate skin proteins and thus reduce the size of the opening through which perspiration is discharged. . . . these preparations may reduce the flow of perspiration, but do not stop it entirely.[31]

Most of the astringent compounds used in the manufacture of antiperspirants have pH values in the acid range; however when the solutions are buffered the acidity is neutralized.

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[29] Ibid.

[30] ________ "Some Basic Facts About Deodorants and Antiperspirants," Consumer Reports (July 1959), 380.

[31] J. Kalish, Op. cit., 265.

Buffering is accomplished by mixing the aluminum sulfate or chloride with a compound that neutralizes the acidity produced by hydrolysis, by using soluble aluminum salts of weak acids, or by preparing self-buffered aluminum compounds such as the aluminum chlorohydroxide complex.[32]

The aluminum chlorohydroxide complex is often combined with hexachlorophene, and it is the most common astringent salt in use today.

Following is a list of active ingredients which appear on the labels of every major brand of antiperspirant sold in the United States:

ASTRINGENT SALTS	DEODORANT ADDITIVES
Aluminum chlorohydroxide complex	benzalkonium chloride
Aluminum chloride	di- and tri-bromo salicylanilide
Aluminum formate	hexachlorophene (G-11)
Aluminum isopropylate di (o-methyl glycolate)	neomycin sulfate
Aluminum sulfamate	
Aluminum sulfate	p-chloro m-xylenol[33]
Sodium zirconium lactate	
Sodium aluminum chlorohydroxy complex	
Zinc borate	
Zinc phenol sulfonate	
Zirconium chloride	

Forms of Deodorants and Antiperspirants Available Commercially

Deodorants and antiperspirants are available on the market in powder, liquid, lotion, cream, and stick forms. The powder deodorants are prepared for foot and body use. This particular form is based upon colloidal kaolin which provides effective moisture absorption, and it

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[32] Ibid.

[33] Robert L. Goldemberg, "Cosmetic Formulating: Possible Applications in Dermatologic Practice." (paper read at the XXI Annual Meeting of the American Academy of Dermatology, Chicago, Illinois, December 6, 1962).

contains talc which makes a smooth-flowing powder and also prevents caking. The antibacterial and deodorizing properties are achieved by the addition of a low solubility phenolic derivative. An aluminum compound provides the astringent characteristics of the powder.

Liquid deodorants consist of an antibacterial and a perfume which are dissolved in alcohol and diluted in water. The liquid antiperspirants contain an astringent salt, in a 10 to 20 per cent concentration, and a few per cent of a high boiling liquid solvent, such as glycerin, which leaves a liquid film on the skin.

In lotion preparations there is a 15 to 20 per cent aluminum salt concentration and the lotion emulsifier which can be a mixture of glyceryl or polyoxyethylene fatty acid esters or fatty alcohol ethers. Cream preparations are of the same constituents as are the lotion preparations; however the emulsifier and astringent compounds have higher concentrations.

"Deodorant sticks are alcohol formed into a solid gel by means of sodium stearate." In addition there is a low concentration of water and an eight per cent concentration of soap.[34]

Deodorant and Antiperspirant Effects on Fabrics

When preparations containing an acid salt come in contact with fabrics, acid damage to the fabrics often occurs. In a series of tests conducted by the American Institute of Laundering in 1943, it was

[34]Kalish, op. cit., 266.

pointed out ". . . that paste deodorants are less injurious than liquid deodorants, and that some antiperspirants and deodorants are harmless to fabrics."[35]

From a study of the action of antiperspirant creams on fabrics, it was found that acid damage readily affects linen, cotton and viscose rayon. The silk, wool and acetate rayon fabrics are extremely susceptible to acid damage. "Maximum damage is produced without preliminary laundering. Creams which contain no buffering ingredient will usually cause complete destruction of cotton, linen and viscose rayon when so treated."[36]

The paper by Bien outlines a laboratory method and practical use procedure for determining the destructiveness of antiperspirant creams on fabrics. It was found that the antiperspirant creams which produced a reduction in tensile strength of less than 20 per cent by the laboratory method caused negligible damage in use.[37] Conclusions of the study were incomplete; however it was found that the pH range, the presence of humectants and buffers, and the type of emulsions used determine antiperspirant effects on fabrics.[38]

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[35] Textile Notes, "Deodorant Damage to Fabrics," A report prepared by the Department of Research and Textiles, American Institute of Laundering (Joliet, Illinois, 1943).

[36] R. R. Bien, "The Action of Antiperspirant Creams on Fabrics," Proceedings of the Scientific Section of the Toilet Goods Association, Number 4 (December 6, 1945).

[37] S. L. Plechner, Cosmetics: Science and Technology (Interscience) 1957, Chapter 32, 719.

[38] Ibid.

Antiperspirants contain astringent compounds with pH values in the acid range. "Where the acidity is substantial and due to a mineral acid of low volatility, textiles in contact with the treated skin area will eventually be weakened and discolored."[39]

Buffering the antiperspirant solutions has overcome a great deal of the fabric damage problem.

III. FUME FADING AND THE EFFECT ON FABRICS

Definition of Fume Fading

Fume fading is a term which is not new to the textile industry. The phenomenon of fume fading has been a common occurrence since the advent of cellulose acetate, but few people understand what it is and what causes it to occur. Fume fading, generally termed gas fading by textile manufacturers, is a color change on fabrics, but in order to be more specific the following definitions have been adopted:

> Gas fading is the fading of a dyed fabric by acidic gases in the atmosphere which are formed in combustion processes.[40]
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> Gas fading is the term applied to the reddening that occurs when fabrics dyed with certain of the blue anthraquinones are exposed in service to atmospheres contaminated with industrial wastes.[41]

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[39] J. Kalish, loc. cit.

[40] V. S. Salvin, W. D. Paist, W. J. Myles, "Advances in Theoretical and Practical Studies of Gas Fading," American Dyestuff Reporter (May 12, 1952), 297.

[41] V. S. Salvin and R. A. Walker, "Correlation Between Colorfastness and Structure of Anthraquinone Blue Disperse Dyes," Textile Research Journal (May 1960), 381.

Causes of Fume Fading

When the first cases of fume fading were observed on cellulose acetate the color changes were regarded as being a result of unsatisfactory dyestuffs or unsuitable fabrics.[42] However as the number of fume fading incidents increased, the source of the difficulty was found to be related to the chemistry of the fiber and the dyestuffs used in the manufacture of the fabric.

The earliest investigations on the cause of fume fading were carried out by Goodall in 1935, and from his studies the first true cause of fume fading was discovered. The cause was recognized as being the action of the oxides of nitrogen on dyed cellulose acetate.[43] Further investigations were carried out in the same decade by Rowe and Chamberlain. They stated that gas fading was greatly dependent on the type of dyestuff used on the fabric. From their studies certain anthraquinone dyes were found to be,

> . . . particularly sensitive to gas fumes; in addition they indicated that the degree of sensitivity of these anthraquinone dyestuffs was connected to some extent with the degree of basicity of the dye, i.e., the number of amino groups contained in the dyestuff molecule.[44]

The blue, violet and red aminoanthraquinone dyes are the most susceptible

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[42]H. B. Goldstein, "Research Has Solved Acetates Big Problem Gas Fading," Textile Forum (April 1953), 21.

[43]Ibid.

[44]Ibid.

to gas fading, but in addition to these certain of the azo acetate dyes are vulnerable to changes in shade.[45]

Soon after the problem of gas fading was recognized as an occurrence, attempts were made to establish laboratory methods of reproducing the gas fading phenomenon. "It was necessary to have a satisfactory test method of this sort in order to intelligently choose the best possible available dyestuff. . .[46]

In 1940 Charles Siebert showed that gas fading was affected by temperature, humidity and the rate of gas consumption. These findings were discovered by Ray, Mack and Wachter at the Ellen H. Richards Institute at The Pennsylvania State College.[47] "The work of refining and perfecting test procedures for determination of gas fading has been carried out by many independent laboratories and workers in particular by the American Association of Textile Chemists and Colorists Research Subcommittee on atmospheric fading."[48]

Atmospheric Contaminants

The oxide of nitrogen which is primarily responsible for gas fading is nitrogen dioxide.[49] In a recent study it has been shown that

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[45]Salvin, Paist, and Myles, loc. cit.

[46]Goldstein, loc. cit.

[47]F. K. Ray, P. B. Mack, A. H. Wachter, "Evaluation of Uncontrolled Gas Fading Equipment," American Dyestuff Reporter (May 3, 1948).

[48]Goldstein, op. cit., 22.

[49]Salvin, Paist, and Myles, loc. cit.

if ozone is present in the atmosphere in sufficient quantities ozone fading will occur.[50] In addition to the oxides of nitrogen and ozone the atmosphere contains a number of other chemicals which react with dyes and fibers to produce color changes. Dr. Victor Salvin, chairman of the Committee on Colorfastness of Textiles to Atmospheric Contaminants, lists the other contaminants to include: ". . . sulfur dioxide, carbon monoxide, hydrocarbons from gasoline combustion, various peroxides of hydrocarbons, and in addition there may be industrial acid fumes.[51] In the atmosphere where there is high humidity the action of these chemicals on the dyes and fibers is accelerated.[52]

Fabrics Susceptible to Fume Fading

Color changes because of the action of atmospheric gases on fibers are found on fabrics using cellulose acetate in their construction. Cellulose acetate is an ester of cellulose. That is, it is an organic salt made by the chemical combination of an organic acid which is acetic acid, with an alcohol which is cellulose. Because of this combination the fabric has acid tendencies and properties which differ from rayons which are currently being manufactured. Since the fabric does have an acid nature, it must be given a slight alkaline bath during the processing, however excessive use of an alkaline substance on the fabric

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[50] Salvin and Walker, loc. cit.

[51] V. S. Salvin, "Investigation of Colorfastness of Textiles to Atmospheric Contaminants," American Dyestuff Reporter (December 25, 1961), 29.

[52] Ibid.

causes saponification. When saponification occurs the acid is given up and the cellulose is regenerated which produces the properties of viscose rayon rather than cellulose acetate.[53]

From a series of experiments on the absorption of nitrogen dioxide by various fibers it may be concluded

> . . . that the troublesome gas fading of aminoanthraquinones in cellulose acetate is due to the relatively great solubility of nitrogen dioxide in this material and the low rate of reaction with it. The gas is therefore free to diffuse through the fibers and attack the dyes.[54]

Although there has been a great amount of publicity related to gas fading on cellulose acetate, this is not the only fabric which is subject to attack by atmospheric contaminants. Color changes have also been observed on Celcos, Dacron, wool, and nylon.[55] The azo acetate dyes and the aminoanthraquinones which fade on acetate and Dacron do not fade on wool, Orlon or cotton. The aminoanthraquinone dyes are not used on viscose or cotton, but if they were to be applied to these particular fabrics by vat dyeing, they would fade at a very slow rate.[56] "It should therefore be stressed that the fiber as well as the dye plays a part in gas fading."[57]

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[53] N. Hollen, J. Saddler, <u>Textiles</u>, (New York: The Macmillan Company, 1955) 58 - 60.

[54] Salvin, Paist, and Myles, <u>op</u>. <u>cit</u>., 299.

[55] <u>Ibid</u>.

[56] <u>Ibid</u>., 297.

[57] <u>Ibid</u>.

Methods of Inhibiting Fume Fading

Two methods employed by textile manufacturers to reduce gas fading have proved to be quite expensive and impractical. These methods are by a partial saponification of the fabric or by coating the fibers with a less permeable polymer coating. A more successful method of reducing fume fading has been through the use of fume fading inhibitors of which there are two types, fugitive and substantive.[58] The fugitive inhibitors,

> . . . give reasonable protection, depending on the depth of shade and the sensitivity of the dyes. Their protection is reduced by perspiration and lost in washing. . . . This type inhibitor acts by maintaining an alkaline condition on the fabric, under which reactions of gas fading do not occur.[59]

A fugitive inhibitor such as triethanolamine or melamine must be applied in a finishing treatment.

The second type of fume fading inhibitor is the permanent-substantive type such as diphenylethylenediamine, which can be applied to the fabric during the dyeing process. This type of inhibitor is somewhat yellow and produces a discoloration on pastel shades which is as objectionable as the effects of fume fading.[60]

Summary

Perspiration is a complex body excretion composed of both organic and inorganic matter. The quantity and composition vary as affected by many factors.

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[58] Ibid., 299.

[59] Ibid.

[60] Ibid.

Fresh perspiration has practically no harmful effects on fabric strength. However, fresh perspiration can cause damage to dyes and finishes. Most of the basic dyes and some direct and metallic dyes are subject to a discoloration which is a result of either a bleeding or staining action. Vat dyes, acid dyes and developed colors are fast to fresh perspiration. Finishes likely to be affected are those of an alkaline nature such as germicides or fungicides.

Perspiration which has decomposed has a greater destructive action on fabrics. Tensile strength of fabrics of all animal or vegetable fibers is reduced. The extent of the damage is influenced by (1) the alkalinity of the perspiration; (2) the length of time the fabric is exposed; (3) the number of contacts; (4) the moisture of the fabrics; and (5) the use of harsh detergents having an excess of alkali. Basic dyes bleed, fade or stain when in contact with contaminated perspiration while vat dyes and developed colors are less affected than other types of dyes. Finishes of both acid and alkaline natures are affected. This would include finishes such as finishing oils, water-proofing and fire-proofing chemicals and fire retardants as well as germicides or fungicides.

The use of antiperspirants to reduce the amount of perspiration produced by the body do not completely eliminate perspiration and do not adequately protect the fabric. When these preparations containing an acid salt come in contact with fabrics, acid damage often occurs. Paste deodorants are less injurious than liquid deodorants. Antiperspirants readily affect linen, cotton, viscoses, silk, wool and acetate fabrics if not buffered. No references were made to the effect of these compounds upon color.

Fume fading is generally recognized as the result of the action of oxides of nitrogen on dyed cellulose acetate. The fading, however, is dependent upon the type of dyestuff used on the fabric. Blue, violet and red anthraquinone dyes are most susceptible but certain of the azo-acetate dyes are also affected.

Recent research indicates that color changes have also been observed on fabrics of Dacron, wool, and nylon and would be likely to occur on viscose or cotton if the aminoanthraquinone dyes could be applied to these fabrics. It has also been found that atmospheric contaminants other than oxides of nitrogen and ozone may react with dyes and fibers to produce color changes. Some of these are sulfur dioxide, carbon monoxide, hydrocarbons from gasoline combustion, peroxides of hydrocarbons and industrial fumes.

Fume fading inhibitors have been effective in reducing the effects of fume fading. Fugitive inhibitors which act by maintaining an alkaline condition on the fabric give reasonable protection but the effectiveness is reduced by perspiration and is lost in washing. The substantive (permanent) inhibitor is applied during the dyeing process. While effective as an inhibitor, a discoloration is produced on pastel colors that is frequently as objectionable as the effects of fume fading.

CHAPTER III

PROCEDURE

Since this study will serve as a basis for continued research in the area of colorfastness to perspiration, antiperspirants and atmospheric fumes, the selection of acetate fabrics to be used as stain test samples for experimentation was made under the direction of textile research personnel. The selected acetate fabrics were specially dyed for this study. A list of the selected acetate fabrics, the applied dyes and the finishing treatments is included in this chapter.

The non-acetate fabrics which were used in this study included fabrics of varied fiber content that were of known dye types. The selected non-acetate fabrics represented fabrics which had been prepared commercially with the dye types that are commonly used in dying the various fibers. The non-acetate fabrics were not specially dyed for this study. A list of the selected non-acetate fabrics, the dye types, and the finishing treatments is included in this chapter.

The chemicals used as antiperspirants were specially prepared and supplied by research personnel of cosmetic firms.

I. Fabrics Used for Experimentation

Selection of Acetate Fabrics

The selection represented acetate fabrics specially prepared with known dyeings. One group, designated as Class A dyes, was fast to light acid and fumes. Another group, designated as Class B conventional dyes was subject to changes in color particularly when exposed to fumes and also was likely to be affected by acid-base changes. The dyes used in each class were as follows:

Class A dyes
1. Eastman Blue B-GLF
2. Eastone Red N-GLF
3. Interchem Yellow H-DLF 40

Class B Dyes
1. Eastman Blue BNN
2. Celliton Pink B
3. Celliton Yellow G

Finishes Applied to Acetate Fabrics

Chemicals which are used commercially to prevent fume fading were applied to one of the Class B dyed fabrics which had been dyed with Eastman Blue BNN. One dyeing of Eastman Blue BNN was finished with a fugitive inhibitor, a 10% solution of triethanolamine. Another dyeing of Eastman Blue BNN was treated with Permalene AF, diphenylethylenediamine which is a substantive inhibitor. The fabrics and finishing treatments are listed in Table I. The code used for experimentation is also included in this table.

The order of fabrics as shown on Table I was fixed rather than randomized. Only the application of the solutions of perspiration and antiperspirants was done at random.

Selection of Non-Acetate Fabrics

The selection of non acetate fabrics included fabrics of varied fiber content that were of known dye types. The non-acetate fabrics used in the study include:

TABLE I

FABRICS, FINISHING TREATMENTS AND CODE FOR EXPERIMENTATION

Fabrics used	Code
Acetate Class A Dyed Fabrics	
Eastman Blue BGLF	A
Eastone Red NGLF	B
Interchem Yellow HDLF	C
Acetate Class B Conventional Dyed Fabrics	
Eastman Blue BNN	
Finished neutral	D_1
Fugitive inhibitor triethanolamine	D_2
Substantive Inhibitor Permalene AF	D_3
Celliton pink	E
Celliton yellow	F
Non Acetate Fabrics	
Kodel and cotton combination	G
65% Type III Kodel, Disperse Dyed	
35% cotton, vat dyed	
100% cotton	H
Mercerized, sanforized, resin finish (DMEU)	
Vat dyed	
100% cotton	I
Vat dyed	
Nylon tricot	J
Disperse dyed	
100% Rayon	K
Direct dyed	
Dacron and wool combination	L
55% Dacron polyester, not dyed	
45% wool, piece dyed with acid dye	

1. Kodel and cotton combination, 65% Type III Kodel disperse dyed, and 35% cotton vat dyed. The fabric was treated with a resin finish Dimethylolethyleneurea (DMEU).

2. Cotton, vat dyed. This fabric was mercerized and sanforized. It was also treated with a resin finish (DMEU).

3. 100% cotton, vat dyed.

4. Nylon tricot, disperse dyed.

5. 100% rayon, direct dyed.

6. Dacron and wool combination, 55% Dacron polyester, not dyed, 45% wool, acid dyed.

II. Solutions of Perspiration and Antiperspirants Used in the Study

Procedure for Testing Colorfastness to Perspiration Solutions

The procedure for testing the colorfastness to perspiration was based on the standard test method for colorfastness to perspiration of the American Association of Textile Chemists and Colorists (15-1962). "Separate specimens of colored textiles are wet out in alkaline and acid solutions, subjected to a fixed mechanical pressure and allowed to dry slowly at slightly elevated temperature. (38°C)[1]

Modifications of this standard test procedure were adapted for this particular study. Since color changes resulting from spotting and staining by perspiration and antiperspirants were of more importance than the fastness of the colors to fading and bleeding, a spotting procedure

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[1] Technical Manual of the American Association of Textile Chemists and Colorists, "Colorfastness to Perspiration," Standard Test Method (15-1962) Volume XXXVIII, B-71.

was adopted rather than the wetting out procedure which was recommended in the standard test procedure of the American Association of Textile Chemists and Colorists. The second modification made in the standard test procedure was the elimination of subjecting the stain test samples to a fixed mechanical pressure. These modifications would more nearly approximate conditions of actual use and facilitate the detection of color changes.

Perspiration Solutions Used in the Study. Perspiration solutions were made up according to the instructions given in the test procedure of the American Association of Textile Chemists and Colorists. The solutions were prepared as follows:

Acid Solution
10 grams sodium chloride
1 gram lactic acid USP 85%
1 gram disodium orthophosphate, anhydrous
.25 gram histidine monohydrochloride

Make up to one liter with distilled water to produce a pH of 3.5.

Alkaline Solution
10 grams sodium chloride
4 grams ammonium carbonate, USP
1 gram disodium orthophosphate, anhydrous
.25 gram histidine monohydrochloride

Make up to one liter with distilled water to produce a pH of 8.0.

Antiperspirant Solutions Used in the Study. The major ingredient in the formulation of most antiperspirants and deodorants was used in this study to represent the products which are available commercially. The three chemicals supplied by the manufacturers in concentrations used commercially were:

1. Aluminum Sulfate, 10% concentration, pH adjusted to 3.2 with Sodium Hydroxide
2. Aluminum Chlorohydroxide, 10% solution, pH 4.2
3. Aluminum Chloride, 25% aqueous solution buffered, pH adjusted to 4.2

Application of Perspiration and Antiperspirant Solutions

Since color changes resulting from spotting and staining by perspiration and antiperspirants were of more importance in this study than the fastness of the colors to fading and bleeding, a specific spotting procedure was developed for applying the solutions to the test fabrics.

The test fabrics, marked to differentiate the location of the preparations, were placed on a drying screen which was covered with a terry towel to aid in the absorption of the stain solutions.

Solutions of perspiration and antiperspirants were applied at random to each test fabric. This random application of the solutions was adopted so as to cancel order effects when the evaluations were made. This procedure for applying the solutions to the test fabrics was based on a table of random permutations of sixteen.

Two drops of each antiperspirant solution were applied to the areas specified by the random sampling procedure. When those solutions were absorbed by the test fabrics, two additional drops of the antiperspirant solutions were applied to the same areas. Test fabrics were suspended in a drying oven at 38° C for fifteen minutes.

Following this drying period, four drops of the perspiration solutions were applied to the areas specified. The test fabrics were again suspended in a drying oven at 38° C for six hours. The time was selected on the recommendation of the standard test procedure of the American Association of Textile Chemists and Colorists.[2] It has been pointed out by the American Committee on Colorfastness to Perspiration" . . . that no further change takes place after the first six hours."[3]

In order to remove any chemical deposit from the surface of the material, the test fabrics were immersed in a dry cleaning solvent, perchlorethylene, for three minutes and were then placed on drying screens to air dry before evaluation.

A master table showing the order of stain applications for each test fabric is included as Appendix A.

Procedure for Evaluation of Color Change

The procedure for evaluating the color change was based on the International Geometric Grey Scale with ratings established as follows:

Class 5: Negligible or no change as shown in Grey Scale, Step 5.

Class 4: A change in color equivalent to Grey Scale, Step 4.

Class 3: A change in color equivalent to Grey Scale, Step 3.

Class 2: A change in color equivalent to Grey Scale, Step 2.

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[2] Ibid., Technical Manual of American Association of Textile Chemists and Colorists.

[3] I. R. Teichgraber, "Perspiration Fastness Testing of Textiles," Canadian Textile Journal (December 9, 1960), 66.

Class 1: A change in color equivalent to Grey Scale, Step 1.[4]

Letters A, B, and C were used to further identify the exact type of color change. If the color change was lighter than the original color, the rating was indicated with the appropriate numerical value from the rating scale and the letter A. If the color change was darker than the original color, the rating was indicated with the appropriate numerical value and the letter B. In cases where there was complete change of color to another hue, the change was rated with an appropriate numerical value, regardless of being lighter or darker in value, and the letter C. If the stain appeared to be a settling out of the chemical solution rather than a change in color, the judges were instructed to indicate this with an asterisk.

All color changes were evaluated by three judges not acquainted with the project. The judges made the ratings independently of each other. The form on which ratings were recorded is included as Appendix B.

III. Fume Fading

Procedure for Exposure to Atmospheric Oxides of Nitrogen

The procedure for testing the colorfastness of dyed textiles to atmospheric oxides of nitrogen was based on the Standard Test Method of

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[4] Technical Manual of the American Association of Textile Chemists and Colorists, "Colorfastness to Perspiration," Standard Test Method (15-1962) Vol. XXXVIII, B-71, 1962.

the American Association of Textile Chemists and Colorists (23-1957). "A test specimen and a cutting of a control sample are exposed simultaneously to oxides of nitrogen fumes until the control shows a change corresponding to that of the Standard of Fading."[5]

In this particular study test specimens to which the solutions of perspiration and antiperspirant had been applied were cut in half.

Half of the sample which was to be exposed to the fumes was attached to a strip of white muslin and suspended in the fume fading chamber with a control sample. The second half was retained as the original for evaluation purposes. The natural gas burner was lighted and the flame adjusted so that the temperature would not exceed 160°F. The test specimens remained in the chamber until the control sample showed a change of shade corresponding with the Standard of Fading. One exposure was used for all of the fume fading tests.

Procedure for Evaluation of Color Change

After one exposure period the test specimens were removed from the fume chamber and compared to the respective original test specimens. In order to determine whether or not the perspiration and or antiperspirant solutions had an accelerating effect on fume fading, the stained areas and the background areas of the test samples were given separate ratings.

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[5]Technical Manual of the American Association of Textile Chemists and Colorists, "Colorfastness to Oxides of Nitrogen in the Atmosphere," Standard Test Method (23-1957), Vol. XXXVIII (1962) B-69.

Ratings for the stained areas and for the background areas were judged according to the following scale which was devised for this particular study.

Class	Rating	Shade Change
3	Good	No noticeable change in shade
2	Fair	Slightly noticeable change in shade
1	Poor	Considerable change in shade

These ratings were made by the same judges who had rated the color changes resulting from the perspiration and antiperspirant tests. The judges made the ratings independently of each other.

CHAPTER IV

PRESENTATION OF DATA

I. The Effect of Stain Solutions on Colors in Selected Fabrics

In this section of the study, the selected fabrics were tested to determine the sensitivity of the colors to solutions of perspiration, antiperspirants and a combination of these two factors.

Two replicates of each selected fabric were treated with the stain solutions. The two replicates of each test were evaluated by three judges. The mean of the six evaluations was recorded as the rating of each fabric. The color changes were rated according to the International Geometric Grey Scale with Class 5 indicating no appreciable change in shade, to Class 1 indicating a severe change in shade.

Since there were slight inconsistencies in the ratings for the individual replicates, a tolerance of plus or minus 0.50 was used in analyzing the data. This tolerance allowed for a fairer evaluation of the color changes. The mean color changes were classified according to the following scale:

Class 5 (5.00 to 4.51) no appreciable change in shade

Class 4 (4.50 to 3.51) slight change in shade

Class 3 (3.50 to 2.51) noticeable change in shade

Class 2 (2.50 to 1.51) considerable change in shade

Class 1 (1.50 to 1.00) severe change in shade

The Effect of Water and Perspiration Solutions on Fabric Color

The means of the ratings given by the three judges to the two replicates treated with solutions of distilled water, acid perspiration and alkaline perspiration are presented in Table II.

Distilled Water. In general, the test fabrics which were treated with distilled water showed no appreciable changes in shade as rated by the three judges.

There was no trace of color change recorded by the judges for the acetate fabrics of either dye type or for the fabric treated with the two fume fading inhibitors.

There was no change in shade in the non-acetate Fabrics G, H, I, K and L. The only evidence of color change was detected on Fabric J. The judges were consistent in rating the first replicate of Fabric J as showing a slight change in shade to a darker value (Class 4). The second replicate of Fabric J, however, was rated as showing no appreciable change in shade.

Acid Perspiration. In general, the fabrics which were treated with acid perspiration showed no appreciable changes in shade.

None of the three judges detected any trace of color change in the acetate Fabrics A, C, D_1, E, and F. Judge 3 indicated that one replicate of Fabric B showed a slight change in shade to a darker value (Class 4).

There was no trace of color change recorded for the acetate Fabrics D_2 and D_3.

The three judges were consistent in indicating that the colors of the non-acetate Fabrics H, K and L were not subject to changes in

TABLE II

MEAN RATINGS GIVEN FABRICS TREATED WITH DISTILLED WATER AND PERSPIRATION SOLUTIONS
(Ratings represent evaluations given by three judges to two replicates)

Fabrics		Distilled water	Acid perspiration	Alkaline perspiration
Acetates uninhibited				
A	Eastman blue BGLF	5.00	5.00	5.00
B	Eastone red NGLF	5.00	4.83	4.83
C	Interchem yellow HDLF	5.00	5.00	5.00
D_1	Eastman blue BNN	5.00	5.00	5.00
E	Celliton pink	5.00	5.00	5.00
F	Celliton yellow	5.00	5.00	5.00
	Mean	5.00	4.97	4.97
Acetates inhibited				
D_2	Fugitive inhibitor Triethanolamine	5.00	5.00	5.00
D_3	Substantive inhibitor Permalene AF	5.00	5.00	5.00
	Mean	5.00	5.00	5.00
Non-acetates				
G	Kodel-cotton combination Kodel, disperse dyed Cotton, vat dyed	5.00	4.67*	4.83
H	100% cotton, vat dyed	5.00	5.00	5.00
I	100% cotton, vat dyed	5.00	5.00	5.00
J	Nylon tricot, disperse dyed	4.50	3.83*	5.00
K	100% rayon, direct dyed	5.00	5.00	5.00
L	Dacron-wool combination Dacron, not dyed Wool, acid dyed	5.00	5.00	5.00
	Mean	4.92	4.75	4.97

*Indicates a chemical deposit on the surface of the fabric.

shade when treated with acid perspiration. Slight changes in shade (Class 4) were reported on individual replicates of Fabric I, G and J. The changes which were detected for Fabrics G and J appeared to be chemical deposits on the surfaces of the fabrics rather than changes in color.

Alkaline Perspiration. For the most part the test fabrics which were treated with the solution of alkaline perspiration showed no appreciable changes in shade. Slight changes were noted on individual replicates of one fabric in each group.

The only trace of color change recorded for the acetate fabrics was a slight change in shade to a darker value on the first replicate of Fabric B.

Each of the judges detected a slight change of shade to a darker value in the first replicate of Fabric D_2.

Judge 3 detected a stain, resulting from a chemical deposit, on the second replicate of Fabric G.

The Effect of Antiperspirant Solutions on Fabric Color

The three judges detected more evidence of color change in fabrics treated with the solutions of antiperspirants than in the same fabrics treated with the solutions of acid or alkaline perspiration. The mean ratings of the evaluation of color changes in fabrics treated with the three antiperspirant solutions are presented in Table III.

Aluminum Sulfate. The acetate Fabrics C and F were not affected by the aluminum sulfate. These were the only fabrics to receive a Class 5 rating. Acetate Fabrics A, B, D_1, and E showed slight traces of change in shade to darker values (Class 4).

TABLE III

MEAN RATINGS GIVEN FABRICS TREATED WITH ANTIPERSPIRANT SOLUTIONS
(Ratings represent evaluations given by three judges to two replicates)

Fabrics		Aluminum sulfate	Aluminum chlorohydroxide	Aluminum chloride
Acetates uninhibited				
A	Eastman blue BGLF	4.00	3.00	2.66
B	Eastone red NGLF	4.33	4.00	2.83
C	Interchem yellow HDLF	5.00	4.50	4.16
D_1	Eastman blue BNN	4.16	3.33	3.33
E	Celliton pink	4.00	3.33	3.00
F	Celliton yellow	5.00	4.16	4.00
	Mean	4.41	3.72	3.33
Acetates inhibited				
D_2	Fugitive inhibitor Triethanolamine	2.33	1.66	1.33*
D_3	Substantive inhibitor Permalene AF	4.50	3.33	2.83
	Mean	3.41	2.50	2.08
Non-acetates				
G	Kodel-cotton combination Kodel, disperse dyed Cotton, vat dyed	4.00	3.83	3.50
H	100% cotton, vat dyed	3.50*	3.50	2.00*
I	100% cotton, vat dyed	3.33*	3.00	3.33*
J	Nylon tricot, disperse dyed	3.16*	3.00	4.00
K	100% rayon, direct dyed	3.83*	2.33	2.00
L	Dacron-wool combination Dacron, not dyed Wool, acid dyed	4.33	5.00	5.00
	Mean	3.69	3.44	3.30

*Indicates a chemical deposit on the surface of the fabric.

Fabric D_2 showed considerable change in shade to a darker value. The judges were consistent in rating the first replicate of Fabric D_3 as showing a slight change in shade to a darker value. The second replicate, however, showed no appreciable change in shade.

The judges detected slight traces of change in shade to a lighter value on the non-acetate Fabric L. In Fabric G a slight trace of change in shade to a darker value was detected. The judges indicated that the stains which appeared on the non-acetate Fabrics H, I, J and K were chemical deposits on the surfaces of the fabrics rather than changes in shade.

<u>Aluminum</u> <u>Chlorohydroxide</u>. All of the fabrics which were treated with this antiperspirant showed appreciable changes in shade except Fabric L of the non-acetate group.

Three of the acetate Fabrics B, C and F showed slight traces of change in shade to darker values. Fabrics A, D_1, and E showed the most noticeable changes of shade in this particular group of fabrics with ratings averaging 3.00, 3.33 and 3.33 respectively.

The inhibited Fabric D_2 showed pronounced change in shade to a lighter value. The mean of the ratings for this fabric was 1.66. Fabric D_3 showed noticeable change in shade to a darker value. In this case the mean of the ratings was 3.33.

The only fabric in the non-acetate group which was not affected by this antiperspirant was Fabric L. Fabric G showed a slight change in shade to a darker value (Class 4). Fabrics I and H showed noticeable changes in shade to lighter values (Class 3). Fabrics J and K showed considerable changes in shade to darker values (Class 2) when treated with aluminum chlorohydroxide.

Aluminum chloride. This solution affected all of the acetate fabrics in both the uninhibited and inhibited fabric groups. All but one of the non-acetate fabrics were affected by this antiperspirant.

Fabrics C and F showed slight traces of changes in shade to darker values (Class 4). Fabrics A, B, D_1 and E showed noticeable changes in shade to darker values. The means of the ratings for these fabrics were 2.66, 2.83, 3.33 and 3.00 respectively.

The solution of aluminum chloride had harmful effects on the colors of both of the inhibited acetate fabrics. The stain which occurred on Fabric D_2 appeared to be a chemical deposit rather than a change in shade. Fabric D_3 showed a noticeable change in shade to a darker value. The mean of the ratings for this fabric was 2.83.

Fabric L of the non-acetate group was the only fabric which was not affected by this antiperspirant. The judges detected a slight trace of change in shade to a darker value on Fabric J. Fabric G showed a noticeable change in shade to a darker value. The 100 per cent cotton Fabrics I and H had pronounced staining characteristics. However, the stains which occurred on these fabrics were indicated as chemical deposits rather than distinct changes in shade. The judges detected a considerable change of shade to a darker value on Fabric K, (Class 2).

The Effect of Combinations of Acid Perspiration and the Antiperspirant Solutions on Fabric Color.

The means of the ratings given by each of the three judges to the two replicates treated with acid perspiration and each of the three antiperspirant solutions are presented on Table IV.

TABLE IV

MEAN RATINGS GIVEN FABRICS TREATED WITH ACID PERSPIRATION AND ANTIPERSPIRANT SOLUTIONS
(Ratings represent evaluations given by three judges to two replicates)

Fabrics		Acid perspiration and Aluminum Sulfate	Acid perspiration and Aluminum Chlorohydroxide	Acid perspiration and Aluminum Chloride
Acetates uninhibited				
A	Eastman blue BGLF	4.00	3.50	3.33
B	Eastone red NGLF	4.16	3.66	3.33
C	Interchem yellow HDLF	5.00	4.50	4.00
D_1	Eastman blue BNN	3.83	3.83	3.33
E	Celliton pink	4.16	3.33	3.16
F	Celliton yellow	5.00	4.50	4.00
	Mean	4.35	3.89	3.52
Acetates inhibited				
D_2	Fugitive inhibitor Triethanolamine	2.33	2.00*	1.33*
D_3	Substantive inhibitor Permalene AF	4.50	4.00	3.16
	Mean	3.41	3.00	2.25
Non-acetates				
G	Kodel-cotton combination Kodel, disperse dyed Cotton, vat dyed	3.50*	4.00	3.33*
H	100% cotton, vat dyed	3.16*	4.00	2.83*
I	100% cotton, vat dyed	4.83	4.16*	2.66*
J	Nylon tricot, disperse dyed	3.83	3.00	4.00
K	100% rayon, direct dyed	3.50	2.66	2.66
L	Dacron-wool combination Dacron, not dyed Wool, acid dyed	4.83	5.00	4.83
	Mean	3.94	3.80	3.39

*Indicates a chemical deposit on the surface of the fabric.

Acid Perspiration Combined with Aluminum Sulfate. For the most part the fabrics which were treated with acid perspiration and aluminum sulfate showed appreciable changes in shade.

The acetate Fabrics C and F showed no appreciable changes in shade when treated with acid perspiration and aluminum sulfate. Fabrics A, B, D_1 and E showed slight changes in shade to darker values (Class 4).

Fabric D_2 showed a considerable change in shade to a darker value. The mean of the ratings for this fabric was 2.33. The judges agreed that the first replicate of Fabric D_3 showed a slight change in shade to a darker value, (Class 4), and that the second replicate had no appreciable color change.

Fabrics I and L showed no appreciable color changes. Fabric J changed slightly to a darker value (Class 4). The stains on Fabric G and Fabric H were indicated as chemical deposits. Fabric K changed to another hue when treated with acid perspiration and aluminum sulfate.

Acid Perspiration Combined with Aluminum Chlorohydroxide. The judges recorded color changes on all of the fabrics which were treated with acid perspiration and aluminum chlorohydroxide except Fabrics C and F of the acetate group.

Fabrics B and D_1 showed slight changes in shade to darker values (Class 4). Fabrics E and A showed the most noticeable color changes in the acetate group (Class 3).

Fabric D_2 changed in shade to a lighter value. Judges 2 and 3 rated the change as a chemical deposit. The mean of the ratings for Fabric D_2 was 2.00. Fabric D_3 changed slightly to a darker value. The mean of the ratings for this fabric was 4.00.

The color of Fabric H changes slightly to a lighter value. The color of Fabric G changed slightly to a darker value. Fabric I showed a chemical deposit on the fabric surface. Fabrics J and K showed the most noticeable color changes in the non-acetate group. The means of the ratings for these fabrics were 3.00 and 2.66 respectively.

Acid Perspiration Combined with Aluminum Chloride. With the exception of the non-acetate Fabric L color changes were detected on all of the fabrics which were treated with acid perspiration and aluminum chloride.

The judges reported slight traces of change in shade to darker values for the yellow acetate Fabrics C and F. Acetate Fabrics A, B, D_1, and E changed noticeably to darker values (Class 3).

Fabric D_2 was severely stained with a chemical deposit on the surface of the fabric. Fabric D_3 showed a noticeable change in shade to a darker value (Class 3).

In the non-acetate group of fabrics the color of Fabric J changed slightly to a darker value when treated with the combination of acid perspiration and aluminum chloride. Fabric K showed noticeable shade change to a darker value. The judges indicated noticeable stains on Fabrics G, H and I. These were stains resulting from chemical deposits on the surfaces of the fabrics rather than changes in color.

The Effect of Combinations of Alkaline Perspiration and the Antiperspirant Solutions

The means of the ratings for the replicates treated with alkaline perspiration and each of the three antiperspirant solutions are presented on Table V.

TABLE V

MEAN RATINGS GIVEN FABRICS TREATED WITH ALKALINE PERSPIRATION AND ANTIPERSPIRANT SOLUTIONS

(Ratings represent evaluations given by three judges to two replicates)

Fabrics	Alkaline perspiration Aluminum Sulfate	Alkaline perspiration Aluminum Chlorohydroxide	Alkaline perspiration Aluminum chloride
Acetates uninhibited			
A Eastman blue BGLF	4.00	3.00	2.66
B Eastone red NGLF	3.83	3.33	2.83
C Interchem yellow HDLF	5.00	4.16	4.16
D_1 Eastman blue BNN	4.00	3.83	2.50
E Celliton pink	4.16	3.33	3.33
F Celliton yellow	5.00	4.00	4.00
Mean	4.33	3.60	3.25
Acetates inhibited			
D_2 Fugitive inhibitor Triethanolamine	2.16	1.33*	1.50*
D_3 Substantive inhibitor Permalene AF	4.33	4.00	3.00
Mean	3.25	2.66	2.25
Non-acetates			
G Kodel-cotton combination Kodel, disperse dyed Cotton, vat dyed	2.33*	1.33*	2.33*
H 100% cotton, vat dyed	2.33*	2.83*	2.66*
I 100% cotton, vat dyed	5.00	2.83*	3.33*
J Nylon tricot, disperse dyed	3.66	3.50	3.50
K 100% rayon, direct dyed	3.33	2.83	4.00
L Dacron-wool combination Dacron, not dyed Wool, acid dyed	4.16	5.00	4.50
Mean	3.47	3.06	3.39

*Indicates a chemical deposit on the surface of the fabric.

Alkaline Perspiration Combined with Aluminum Sulfate. There were appreciable changes in shade detected on all fabrics except Fabrics C and F of the acetate group and Fabric I of the non-acetate group.

There were no appreciable changes in shade on the yellow acetate Fabrics C and F. Slight changes in shade to darker values were recorded for all the other fabrics in this group.

Fabric D_2 showed a considerable change in shade to a darker value. The mean of the ratings for this fabric was 2.16. The judges detected a slight change in shade to a darker value on Fabric D_3. The mean of the ratings for this fabric was 4.33.

The non-acetate Fabric I was not affected by the combination of alkaline perspiration and aluminum sulfate. Fabrics J and L showed slight changes in shade to darker values. The judges detected stains which they considered chemical deposits on Fabrics G and H. The color of Fabric K changes to another hue when treated with alkaline perspiration and aluminum sulfate.

Alkaline Perspiration Combined with Aluminum Chlorohydroxide. The combination of alkaline perspiration and aluminum chlorohydroxide affected all of the fabrics except Fabric L of the non-acetate group.

Slight traces of change in shade to darker values were detected on Fabrics C, F, and D_1 (Class 4). Noticeable changes in shade to darker values were detected on Fabrics A, B and E (Class 3).

Fabrics D_3 showed a slight change in shade to a darker value (Class 4). A severe chemical deposit was detected on Fabric D_2.

The colors of Fabrics J and K changed noticeably to darker values. The stains on Fabrics G, H and I were indicated as chemical deposits.

Alkaline Perspiration Combined with Aluminum Chloride. The combination of alkaline perspiration and aluminum chloride affected all of the fabrics.

The yellow acetate Fabrics C and F showed slight traces of change in shade to darker values (Class 4). Noticeable changes in shade to darker values were detected for Fabrics A and E. Fabric D_1 showed a considerable change in shade to a darker value.

The combination of alkaline perspiration and aluminum chloride formed a severe chemical deposit on the surface of Fabric D_2. Fabric D_3 showed a noticeable change in shade to a darker value (Class 3).

In the non-acetate group of fabrics, Fabric L showed a slight trace of change in shade to a lighter value. Fabric K showed a slight trace of change in shade to a darker value. There was a noticeable change in shade to a lighter value on Fabric J (Class 3). The stains on Fabrics G, H and I were detected as chemical deposits.

Summary of Data According to Color Sensitivity of Fabric Groups to Stain Test Solutions

The mean ratings indicate that the Class A dyes and the Class B dyes were affected similarly by the stain test solutions. The mean ratings of the evaluation of color changes in the Class A dyed and the Class B dyed acetate fabrics are presented in Table VI.

TABLE VI

MEAN RATINGS FOR COMPARISON OF CLASS A WITH CLASS B DYED ACETATE FABRICS

(Ratings represent evaluations given by three judges to two replicates)

Stains	Acetate fabrics Class A	Class B
Distilled water	5.00	5.00
Acid perspiration	4.94	5.00
Alkaline perspiration	4.94	5.00
Aluminum sulfate	4.44	4.39
Aluminum chlorohydroxide	3.83	3.61
Aluminum chloride	3.22	3.44
Acid perspiration and aluminum sulfate	4.38	4.33
Acid perspiration and aluminum chlorohydroxide	3.89	3.89
Acid perspiration and aluminum chloride	3.55	3.50
Alkaline perspiration and aluminum sulfate	4.28	4.38
Alkaline perspiration and aluminum chlorohydroxide	3.50	3.72
Alkaline perspiration and aluminum chloride	3.22	3.28

Comparison of the Color Sensitivity of the Class A Dyes with the Color Sensitivity of the Class B Dyes. Neither the Class A dyes nor the Class B dyes were affected by acid perspiration or alkaline perspiration.

Aluminum sulfate and aluminum chlorohydroxide produced slight changes in shade on both the Class A and Class B dyed fabrics. Aluminum chloride produced noticeable changes in shade on the fabrics in both groups.

The combinations of acid perspiration with aluminum sulfate and with aluminum chlorohydroxide produced slight changes in shade on both the Class A and Class B dyed fabrics. The combination of acid perspiration and aluminum chloride produced slight changes in shade on the Class A dyes and noticeable changes in shade on the Class B dyes.

Both the Class A and Class B dyes were slightly affected by the combination of alkaline perspiration with aluminum sulfate. Alkaline perspiration and aluminum chlorohydroxide produced noticeable changes in shade on the Class A dyes and slight changes on the Class B dyes. Alkaline perspiration and aluminum chloride produced noticeable changes in shade on both classes of dyes.

Comparison of the Color Sensitivity of the Inhibited Acetate Fabrics with the Color Sensitivity of the Uninhibited Acetate Fabrics. There was little difference in the color sensitivity of the fabric which was finished neutral and the color sensitivity of the fabric which was finished with the substantive inhibitor. The fabric which was finished with the fugitive inhibitor was more sensitive to the stain test solutions. The mean ratings of the evaluation of color changes in Fabrics D_1, D_2 and D_3 are presented in Table VII.

TABLE VII

MEAN RATINGS FOR COMPARISON OF THE INHIBITED AND THE UNINHIBITED ACETATE FABRICS

(Ratings represent evaluation given by three judges to two replicates)

Stains	Fabrics D_1	D_2	D_3
Distilled water	5.00	5.00	5.00
Acid perspiration	5.00	5.00	5.00
Alkaline perspiration	5.00	5.00	5.00
Aluminum sulfate	4.16	2.33	4.50
Aluminum chlorohydroxide	3.33	1.66	3.33
Aluminum chloride	3.33	1.33*	2.83
Acid perspiration and aluminum sulfate	4.00	2.16	4.33
Acid perspiration and aluminum chlorohydroxide	3.83	1.33*	4.00
Acid perspiration and aluminum chloride	2.50	1.50*	3.00
Alkaline perspiration and aluminum sulfate	3.83	2.33	4.50
Alkaline perspiration and aluminum chlorohydroxide	3.83	2.00	4.00
Alkaline perspiration and aluminum chloride	3.33	1.33*	3.16

*Indicates a chemical deposit on the surface of the fabric.

The perspiration solutions had no affect on the color of the uninhibited fabric or on the color of the inhibited fabrics.

Aluminum sulfate produced a slight change in shade on Fabrics D_1 and D_3 and a considerable change in Fabric D_2. Aluminum chlorohydroxide and aluminum chloride produced noticeable changes in shade on the Fabrics D_1 and D_3 and a considerable change on Fabric D_2. Aluminum chloride produced noticeable changes in shade on Fabrics D_1 and D_3; however a severe chemical deposit was produced on Fabric D_2.

The combination of acid perspiration and aluminum sulfate produced slight changes in shade on Fabrics D_1 and D_3, but Fabric D_2 showed a considerable change in shade. Acid perspiration and aluminum chlorohydroxide produced slight changes in shade on Fabrics D_1 and D_3, and a severe chemical deposit on Fabric D_2. Acid perspiration and aluminum chloride produced a noticeable change in shade on Fabric D_3 and a considerable change on Fabric D_1. This combination produced a chemical deposit on Fabric D_2.

The combinations of alkaline perspiration with aluminum sulfate and with aluminum chlorohydroxide produced slight changes in shade on Fabrics D_1 and D_3 and a considerable change in shade on Fabric D_2. The combination of alkaline perspiration and aluminum chloride produced noticeable changes in shade on Fabrics D_1 and D_3 and a chemical deposit on Fabric D_2.

<u>Comparison of the Color Sensitivity of the Selected Acetate Fabrics with Non-Acetate Fabrics</u>. The mean of means for the ratings indicate that the colors of the acetate fabrics and the colors of the non-acetate fabrics were affected similarly by the stain test solutions.

The outstanding difference in the results was the chemical deposits which occurred on some of the non-acetate fabrics particularly Fabrics G, H, I and J. The mean ratings of the evaluation of color changes in the selected acetate fabrics and the selected non-acetate fabrics are presented on Table VIII.

TABLE VIII

MEAN RATINGS FOR COMPARISON OF SELECTED ACETATE WITH SELECTED NON-ACETATE FABRICS

Stains	Acetate fabrics	Non-acetate fabrics
Distilled water	5.00	4.92
Acid perspiration	4.97	4.75
Alkaline perspiration	4.97	4.97
Aluminum sulfate	4.41	3.69*
Aluminum chlorohydroxide	3.72	3.44
Aluminum chloride	3.33	3.30*
Acid perspiration and aluminum sulfate	4.33	3.47*
Acid perspiration and aluminum chlorohydroxide	3.60	3.06
Acid perspiration and aluminum chloride	3.25	3.39*
Alkaline perspiration and aluminum sulfate	4.35	3.94*
Alkaline perspiration and aluminum chlorohydroxide	3.89	3.80*
Alkaline perspiration and aluminum chloride	3.52	3.39*
Mean	4.11	3.84

*Indicates that the solution produced a chemical deposit on a non-acetate fabric.

The perspiration solutions produced no appreciable color changes on either group of fabrics.

Aluminum sulfate produced slight changes in the shade on the acetate fabrics and the non-acetate fabrics. This solution also left chemical deposits on Fabrics H, I, J and K. Aluminum chlorohydroxide produced slight changes in shade on the acetate fabrics and noticeable changes in shade on the non-acetate fabrics. Aluminum chloride produced noticeable changes in shade on both groups of fabrics; however there were deposits on Fabrics H and I.

The combination of acid perspiration and aluminum sulfate produced slight changes in shade on the acetate fabrics. This combination produced noticeable changes in shade on the non-acetate fabrics and also produced chemical deposits on Fabrics G and H. Acid perspiration and aluminum chlorohydroxide produced slight changes in shade on the acetate fabrics and noticeable changes in shade on the non-acetate fabrics. Acid perspiration and aluminum chloride produced noticeable changes in shade on both of the fabric groups. This combination also produced chemical deposits on the non-acetate Fabrics G, H and I.

The combinations of alkaline perspiration with aluminum sulfate and with aluminum chlorohydroxide produced slight changes in shade on the acetate fabrics and the non-acetate fabrics. Both of these combinations resulted in chemical deposits on the non-acetate Fabrics G, H and I. Alkaline perspiration and aluminum chloride produced slight changes in shade on the acetate fabrics and noticeable changes in shade on the non-acetate fabrics. Chemical deposits occurred on Fabrics G, H and I.

II. The Effect of Fumes on Colors in Treated Fabrics

The second section of this study was planned to determine the effects of the oxides of nitrogen on fabrics treated with perspiration and antiperspirants. The test specimens to which the solutions of perspiration and antiperspirant had been applied were cut in half. Half of the sample which was to be exposed to the fumes was attached to a strip of white muslin and suspended in the fume fading chamber for one exposure period. The test specimens were compared to the respective original test specimens. The stained areas and the background areas were given separate ratings according to the following scale:

Class 3, no noticeable change in shade

Class 2, slightly noticeable change in shade

Class 1, considerable change in shade

Since there were slight inconsistencies in the ratings for the individual replicates, a tolerance of plus or minus 0.50 was used in analyzing the data. The color changes were classified according to the following scale:

Class 3 (3.00 to 2.51) no noticeable change in shade

Class 2 (2.50 to 1.51) slightly noticeable change in shade

Class 1 (1.51 to 1.00) considerable change in shade

The Effect of Fumes on the Background Areas

The means of the ratings for the background areas of the replicates which were exposed to the fumes are presented in Table IX.

Class A Dyed Fabrics. The background areas of Fabrics B and C were not affected by the fumes. The background area of Fabric A showed slightly noticeable changes in shade.

Class B Dyed Fabrics. The background area of Fabric F was not

TABLE IX

MEAN RATINGS GIVEN BACKGROUND AREAS EXPOSED TO THE FUMES

(Ratings represent evaluations given by three judged to two replicates)

Fabrics	Mean
Class A dyed	
A Eastman blue BGLF	2.15
B Eastone red NGLF	2.96
C Interchem yellow HDLF	2.96
Mean	2.69
Class B dyed	
D_1 Eastman blue BNN	2.16
E Celliton pink	2.04
F Celliton yellow	3.00
Mean	2.40
Inhibited	
D_2 Fugitive inhibitor Triethanolamine	1.48
D_3 Substantive inhibitor Permalene AF	2.00
Mean	1.74
Non acetate	
G Kodel-cotton combination Kodel, disperse dyed Cotton, vat dyed	2.61
H 100% cotton, vat dyed	2.95
I 100% cotton, vat dyed	3.00
J Nylon tricot, disperse dyed	2.65
K 100% rayon, direct dyed	3.00
L Dacron-wool combination, Dacron not dyed Wool, acid dyed	3.00
Mean	2.87

affected by the fumes. The background areas of Fabrics D_1 and E showed slightly noticeable changes in shade.

Inhibited Fabrics. The background area of Fabric D_3 showed a slightly noticeable change in shade when exposed to the fumes. The background area of Fabric D_2 showed a considerable change in shade.

Non-Acetate Fabrics. The background areas of all of the non-acetate fabrics were unaffected by the fumes.

The Effect of Fumes on Color of Fabrics Treated with Distilled Water and Perspiration Solutions

The means of the ratings for the replicates which were treated with distilled water and acid perspiration, alkaline perspiration and exposed to the fumes are presented on Table X.

Distilled Water. There were no noticeable changes in shade on the Class A dyed acetate fabrics. The Class B dyed acetate Fabric F was not affected by the fumes, however Fabrics D_1 and E showed slight changes in shade.

The judges detected a slight change in Fabric D_2. The mean of the ratings for this fabric was 2.00. The mean of the ratings for Fabric D_3 was 2.66.

The only trace of color change in the non-acetate fabrics was detected on Fabric G. The mean of the ratings for this fabric was 2.66.

Acid Perspiration. There were no noticeable changes in shade of the colors in Class A dyed acetate fabrics. Fabric F of the Class B dyed acetate fabrics was not affected by the fumes. The color of Fabric D_1 showed a slight change in shade and the color of Fabric E showed considerable change in shade.

The judges indicated that Fabrics D_2 and D_3 showed slight changes in shade when exposed to the fumes.

No noticeable color changes were detected on the non-acetate fabrics.

Alkaline Perspiration. There were no noticeable changes in shade on the Class A dyed acetate fabrics. Fabric F of the Class B dyed acetate fabrics was not affected by the fumes. The colors of Fabrics D_1 and E showed considerable changes in shade.

TABLE X

MEAN RATINGS GIVEN FABRICS TREATED WITH DISTILLED WATER, PERSPIRATION SOLUTIONS AND EXPOSED TO FUMES
(Ratings represent evaluations given by three judges to two replicates)

Fabrics	Distilled water	Acid perspiration	Alkaline perspiration
Acetates uninhibited			
A Eastman blue BGLF	2.83	2.83	2.83
B Eastone red NGLF	3.00	3.00	3.00
C Interchem yellow HDLF	3.00	3.00	3.00
D_1 Eastman blue BNN	2.00	2.00	1.50
E Celliton pink	2.33	1.50	1.50
F Celliton yellow	3.00	3.00	3.00
Mean	2.69	2.55	2.47
Acetates inhibited			
D_2 Fugitive inhibitor Triethanolamine	2.00	2.50	2.50
D_3 Substantive inhibitor Permalene AF	2.66	1.83	2.50
Mean	2.33	2.16	2.50
Non-acetates			
G Kodel-cotton combination	3.00	2.83	2.83
Kodel, disperse dyed			
Cotton, vat dyed			
H 100% cotton, vat dyed	3.00	3.00	3.00
I 1 00% cotton, vat dyed	3.00	3.00	3.00
J Nylon tricot, disperse dyed	2.66	2.83	2.83
K 100% rayon, direct dyed	3.00	3.00	3.00
L Dacron-wool combination	3.00	3.00	3.00
Dacron, not dyed			
Wool, acid dyed			
Mean	2.94	2.94	2.94

Slight changes in shade were detected on both of the inhibited acetate Fabrics D_2 and D_3.

There were no noticeable changes in shade on the non-acetate fabrics.

The Effect of Fumes on Colors of Fabrics Treated With Antiperspirant Solutions

The judges detected more evidence of fume fading in the fabrics treated with the solutions of antiperspirants than in the same fabrics treated with the solutions of acid or alkaline perspiration. The means of the ratings for the replicates which were treated with the antiperspirants and exposed to the fumes are presented on Table XI.

Aluminum Sulfate. There were no noticeable changes in shade of the Class A dyed acetate Fabrics B and C. A slight change in shade was detected on Fabric A by two of the judges. The class B dyed acetate Fabric F was not affected by the fumes, however the colors of Fabrics D_1 and E showed considerable changes in shade (Class 1).

Slight changes in shade were detected on both of the inhibited acetate Fabrics D_2 and D_3.

The judges were not consistent in rating the non-acetate fabrics. The means of the ratings show that the only fabric which was not noticeably affected in this group of fabrics was Fabric L. The colors of the Fabrics G, H, I, J and K showed slight traces of change in shade.

Aluminum Chlorohydroxide. Fabric D of the Class A dyed acetate fabrics was the only one not affected by the fumes. The colors of Fabrics B and A showed slight traces of change in shade. Fabric F of the

TABLE XI

MEAN RATINGS GIVEN FABRICS TREATED WITH ANTIPERSPIRANT SOLUTIONS AND EXPOSED TO FUMES
(Ratings represent evaluations given by three judges to two replicates)

Fabrics	Aluminum Sulfate	Aluminum Chlorohydroxide	Aluminum Chloride
Acetates uninhibited			
A Eastman blue BGLF	2.66	2.33	2.50
B Eastone red NGLF	3.00	2.66	2.83
C Interchem yellow HDLF	2.83	3.00	2.83
D_1 Eastman blue BNN	1.00	1.00	1.00
E Celliton pink	1.00	1.00	1.00
F Celliton yellow	3.00	3.00	3.00
Mean	2.25	2.16	2.19
Acetates inhibited			
D_2 Fugitive inhibitor Triethanolamine	1.66	1.33	1.33
D_3 Substantive inhibitor Permalene AF	2.00	1.16	1.00
Mean	1.83	1.25	1.16
Non-acetates			
G Kodel-cotton combination Kodel, disperse dyed Cotton, vat dyed	2.50	2.83	2.16
H 100% cotton, vat dyed	2.66	2.50	2.33
I 100% cotton, vat dyed	2.33	2.50	2.50
J Nylon tricot, disperse dyed	2.50	2.33	2.16
K 100% rayon, direct dyed	2.50	2.16	2.16
L Dacron-wool combination Dacron, not dyed Wool, acid dyed	2.83	3.00	3.00
Mean	2.55	2.55	2.39

Class B dyed acetate fabrics was not affected by the fumes; however the colors of Fabrics D_1 and E showed considerable change in shade (Class 1).

Both of the inhibited acetate Fabrics D_2 and D_3 showed considerable changes in shade.

The only two non-acetate fabrics which were not affected by the fumes were Fabrics G and L. Fabrics H, I, J and K showed slight changes in shade.

Aluminum Chloride. The Class A dyed acetate Fabrics B and C did not show any changes in shade. The color of Fabric A showed a slight change in shade. Fabric F of the Class B dyed acetate fabrics showed no change in shade; however Fabrics D_1 and E showed considerable changes in shade.

Fabrics D_2 and D_3 showed considerable change in shade (Class 1).

In the non-acetate group Fabric L was not affected by the fumes. Fabrics G, H, I, J and K showed slight change in shade (Class 2).

The Effect of Fumes on the Colors of Fabrics Treated with Acid Perspiration and Each of the Antiperspirants

The means of the ratings for each of the replicates treated with acid perspiration and each of the antiperspirants and exposed to the fumes are presented in Table XII.

Acid Perspiration Combined with Aluminum Sulfate. The Class A dyed acetate Fabrics B and C were not affected by the fumes. Two of the judges detected a slight change in shade on one replicate of Fabric A. Fabric F of the Class B dyed acetate fabrics was not affected by the fumes. Fabrics D_1 and E showed considerable change in shade (Class 1).

TABLE XII

MEAN RATINGS GIVEN FABRICS TREATED WITH ACID PERSPIRATION AND THE ANTIPERSPIRANT SOLUTIONS AND EXPOSED TO FUMES

(Ratings represent evaluations given by three judges to two replicates)

Fabrics	Acid perspiration and Aluminum Sulfate	Acid perspiration and Aluminum Chlorohydroxide	Acid perspiration and Aluminum chloride
Acetates uninhibited			
A Eastman blue BGLF	2.66	2.50	2.66
B Eastone red NGLF	3.00	3.00	2.83
C Interchem yellow HDLF	3.00	3.00	3.00
D_1 Eastman blue BNN	1.00	1.00	1.00
E Celliton pink	1.00	1.00	1.00
F Celliton yellow	3.00	3.00	2.66
Mean	2.28	2.25	2.19
Acetates inhibited			
D_2 Fugitive inhibitor Triethanolamine	1.00	1.50	1.33
D_3 Substantive inhibitor Permalene AF	1.00	1.16	1.16
Mean	1.00	1.33	1.25
Non-acetate			
G Kodel-cotton combination Kodel, disperse dyed Cotton, vat dyed	2.33	2.66	2.66
H 100% cotton, vat dyed	2.33	2.66	2.33
I 100% cotton, vat dyed	3.00	2.83	2.33
J Nylon tricot, disperse dyed	2.50	2.33	2.16
K 100% rayon, direct dyed	2.16	2.16	2.16
L Dacron-wool combination Dacron, not dyed Wool, acid dyed	3.00	2.83	3.00
Mean	2.55	2.58	2.44

Fabrics D_2 and D_3 also showed considerable change in shade (Class 1).

Fabrics L and I of the non-acetate group of fabrics were not affected by the fumes. Fabrics G, H, J and K showed slight traces of change in shade.

Acid Perspiration Combined with Aluminum Chlorohydroxide. There were no noticeable changes in shade on the Class A dyed acetate Fabrics B and C. Fabric A showed slight traces of change in shade. The Class B dyed Fabric F showed no noticeable change in shade; however Fabrics D_1 and E showed considerable changes in shade.

Both of the inhibited acetate Fabrics D_2 and D_3 showed considerable changes in shade (Class 1).

Judge 2 detected the only color change on Fabrics I and L of the non-acetate group of fabrics. The mean of the ratings for these two fabrics was 2.83. Fabrics G, H, J and K showed slight traces of change in shade.

Acid Perspiration Combined with Aluminum Chloride. The only Class A dyed fabric which was not affected by the fumes was Fabric C. Judge 2 detected a slight change in shade on the first replicate of Fabric B. The mean of the ratings for the fabric was 2.83. Judges 2 and 3 detected a slight change in shade on the second replicate of Fabric A. The mean of the ratings for this fabric was 2.66. A slight change of shade was detected on Fabric F of the Class B dyed acetate fabrics. Fabrics D_1 and E showed considerable change in shade as did Fabric D_2 and D_3 of the group to which inhibitors had been applied.

Fabric L was the only non-acetate fabric which was not affected by the fumes. Fabrics G, H, I, J and K showed slight change in shade.

The Effect of Fumes on the Colors of Fabrics Treated with Alkaline Perspiration and each of the Antiperspirants

The means of the ratings for the replicates which were treated with alkaline perspiration and each of the antiperspirants and exposed to the fumes are presented on Table XIII.

Alkaline Perspiration Combined with Aluminum Sulfate. There were no traces of change in shade on the Class A dyed acetate Fabrics B and C. Judges 2 and 3 detected a slight change in shade on one replicate of Fabric A. The mean of the ratings for Fabric A was 2.66. The Class B dyed acetate Fabric F was not affected by the fumes. Fabrics D_1 and E showed considerable change in shade.

Fabrics D_2 and D_3 were both considerably affected by the fumes (Class 1).

The only non-acetate fabric which was not affected by the fumes was Fabric I. Fabrics G, H, J, K and L showed slight traces of change in shade.

Alkaline Perspiration Combined with Aluminum Chlorohydroxide. There was no change of shade detected on the Class A dyed Fabric B. Judge 2 detected a slight change in shade on one replicate of Fabric C. Judges 2 and 3 detected a slight change in shade in the second replicate of Fabric A. Fabric F of the Class B dyed acetate fabrics showed no change in shade; however Fabrics D_1 and E showed considerable color change.

The colors of both of the inhibited acetate Fabrics D_2 and D_3 showed considerable change in shade.

TABLE XIII

MEAN RATINGS GIVEN FABRICS TREATED WITH ALKALINE PERSPIRATION AND THE ANTIPERSPIRANT SOLUTIONS AND EXPOSED TO FUMES

(Ratings represent evaluations given by three judges to two replicates)

Fabrics	Alkaline perspiration and Aluminum Sulfate	Alkaline perspiration and Aluminum Chlorohydroxide	Alkaline perspiration and Aluminum Chloride
Acetates uninhibited			
A Eastman blue BGLF	2.66	2.66	2.33
B Eastone red NGLF	3.00	3.00	2.50
C Interchem yellow HDLF	3.00	2.83	3.00
D_1 Eastman blue BNN	1.00	1.00	1.00
E Celliton pink	1.00	1.00	1.00
F Celliton yellow	3.00	3.00	2.83
Mean	2.28	2.25	2.11
Acetates inhibited			
D_2 Fugitive inhibitor Triethanolamine	1.00	1.50	1.33
D_3 Substantive inhibitor Permalene AF	1.00	1.00	1.00
Mean	1.00	1.25	1.16
Non-acetates			
G Kodel-cotton combination	2.33	2.33	2.16
Kodel, disperse dyed			
Cotton, vat dyed			
H 100% cotton, vat dyed	2.33	2.33	2.33
I 100% cotton, vat dyed	3.00	2.33	2.66
J Nylon tricot, disperse dyed	2.16	2.16	2.50
K 100% rayon, direct dyed	2.33	2.33	2.50
L Dacron-wool combination	2.66	2.50	3.00
Dacron, not dyed			
Wool, acid dyed			
Mean	2.47	2.33	2.52

All of the non-acetate fabrics were affected by the fumes. The ratings of these fabrics indicated slight changes in shade.

Alkaline Perspiration Combined with Aluminum Chloride. There was no trace of color change detected in Fabric C of the Class A dyed acetate fabrics. Fabrics B and A showed slight change in shade. Judge 2 detected the only change for Fabric F of the Class B dyed fabrics. The mean of the ratings for this fabric was 2.83. Fabrics D_1 and E showed considerable color change.

The inhibited acetate Fabrics D_2 and D_3 also showed a considerable color change.

Fabric L of the non-acetate group was the only fabric which was not affected by the fumes. Fabrics G, H, I, J and K showed slight change in shade.

Summary of Data According to the Effect of Fumes on the Stained Areas of Fabric Groups

The mean ratings indicate that the stained areas in the Class A dyed fabrics were faster to the fumes than were the stained areas on the Class B dyed fabrics. Mean ratings for the comparison of the effect of fumes on the stained areas of the Class A and Class B dyed fabrics are presented on Table XIV.

TABLE XIV

MEAN RATINGS FOR COMPARISON OF THE EFFECT OF FUMES ON THE STAINED AREAS ON CLASS A AND CLASS B DYED ACETATE FABRICS

(Ratings represent evaluations given by three judges to two replicates)

Solutions	Acetate fabrics	
	Class A	Class B
Distilled water	2.94	2.44
Acid perspiration	2.94	2.17
Alkaline perspiration	2.94	2.00
Aluminum sulfate	2.40	1.67
Aluminum chlorohydroxide	2.67	1.67
Aluminum chloride	2.72	1.67
Acid perspiration and aluminum sulfate	2.89	1.67
Acid perspiration and aluminum chlorohydroxide	2.50	1.67
Acid perspiration and aluminum chloride	2.83	1.56
Alkaline perspiration and aluminum sulfate	2.89	1.67
Alkaline perspiration and aluminum chlorohydroxide	2.83	1.67
Alkaline perspiration and aluminum chloride	2.61	1.67

Comparison of the Effect of Fumes on the Stained Areas of the Class A Dyed and Class B Dyed Fabrics. The Class A dyes which had been stained with distilled water were not affected by the fumes. The Class B dyes showed slight change in shade. The Class A dyes which had been stained with the perspiration solutions showed no changes in shade; however the Class B dyes showed noticeable changes in shade.

Both classes stained with aluminum sulfate showed slight changes in shade. The Class A dyes stained with the solutions of aluminum chlorohydroxide and with aluminum chloride were not affected by the fumes, however the Class B dyes showed slight changes in shade.

The Class A dyed fabrics stained with the combination of acid perspiration with aluminum sulfate and with aluminum chloride were not affected by the fumes. Noticeable changes were detected on the Class B dyed fabrics and on both groups treated with the combination of acid perspiration and aluminum chlorohydroxide.

The fumes did not affect the Class A dyed fabrics which were stained with the combinations of alkaline perspiration and each of the antiperspirants. The Class B dyed fabrics showed noticeable changes in shade.

Comparison of the Effect of Fumes on the Stained Areas on the Inhibited Acetate Fabrics and the Uninhibited Acetate Fabrics

The fumes affected the stained areas on Fabrics D_1, D_2 and D_3 similarly. The mean ratings for the comparison of the effect of fumes on the stained areas on Fabrics D_1, D_2 and D_3 are presented on Table XV.

TABLE XV

MEAN RATINGS FOR COMPARISON OF THE EFFECT OF FUMES ON THE STAINED AREAS OF THE INHIBITED AND THE UNHIBITED ACETATE FABRICS

(Ratings represent evaluations given by three judges to two replicates)

Solutions	Fabrics		
	D_1	D_2	D_3
Distilled water	2.00	2.00	2.66
Acid perspiration	2.00	2.50	1.83
Alkaline perspiration	1.50	2.50	2.50
Aluminum sulfate	1.00	1.66	2.00
Aluminum chlorohydroxide	1.00	1.33	1.16
Aluminum chloride	1.00	1.33	1.00
Acid perspiration and aluminum sulfate	1.00	1.00	1.00
Acid perspiration and aluminum chlorohydroxide	1.00	1.50	1.16
Acid perspiration and aluminum chloride	1.00	1.33	1.16
Alkaline perspiration and aluminum sulfate	1.00	1.00	1.00
Alkaline perspiration and aluminum chlorohydroxide	1.00	1.50	1.00
Alkaline perspiration and aluminum chloride	1.00	1.33	1.00

On Fabric D_3, the area which had been stained with distilled water was not affected by the fumes. Fabrics D_1 and D_2 showed slight changes in shade.

In all three of the fabrics the areas which were stained with perspiration solutions showed slight color changes.

The stained areas on all three of the fabrics which had been treated with the three antiperspirants, the combinations of acid perspiration with each of the antiperspirants and the combinations of alkaline perspiration with each of the antiperspirants showed considerable changes in shade after fume fading.

Comparison of the Effect of Fumes on the Stained Areas on the Selected Acetate Fabrics and the Selected Non-Acetate Fabrics

The mean ratings indicate that fume fading had more affect on the stained areas on the acetate fabrics than on the stained areas on the non-acetate fabrics. The mean ratings for the comparison of the effect of fumes on the stained areas on the acetate fabrics with the stained areas on the non-acetate fabrics are presented on Table XVI.

TABLE XVI

MEAN RATINGS FOR COMPARISON OF THE EFFECT OF FUMES ON THE STAINED AREAS ON THE SELECTED ACETATE FABRICS AND THE SELECTED NON-ACETATE FABRICS (Ratings represent evaluations given by three judges to two replicates)

Solutions	Acetate fabrics	Non-acetate fabrics
Distilled water	2.69	2.94
Acid perspiration	2.55	2.94
Alkaline perspiration	2.47	2.94
Aluminum sulfate	2.25	2.55
Aluminum chlorohydroxide	2.16	2.55
Aluminum chloride	2.19	2.39
Acid perspiration and aluminum sulfate	2.28	2.55
Acid perspiration and aluminum chlorohydroxide	2.25	2.58
Acid perspiration and aluminum chloride	2.19	2.44
Alkaline perspiration and aluminum sulfate	2.28	2.47
Alkaline perspiration and aluminum chlorohydroxide	2.25	2.33
Alkaline perspiration and aluminum chloride	2.11	2.52

The fabrics in both groups which were treated with distilled water and with acid perspiration were not affected by the fumes.

The stained areas of the non-acetate fabrics which had been treated with alkaline perspiration were not affected by the fumes, however the stained areas on the acetate fabrics showed slight color change.

There were slight changes in shade on the stained areas in the acetate fabrics which had been treated with each of the three antiperspirants. Only the stained areas of the non-acetate fabrics which had been treated with aluminum chloride showed slight changes in shade.

On the acetate fabrics there were slight traces of change in shade on the stained areas which had been treated with the combinations of acid perspiration with each of the antiperspirants and the combinations of alkaline perspiration with each of the antiperspirants. On the non-acetate fabrics there were slight changes in shade on the stained areas which had been treated with the combination of acid perspiration and aluminum chloride, alkaline perspiration and aluminum sulfate and alkaline perspiration and aluminum chlorohydroxide.

CHAPTER V

SUMMARY AND CONCLUSIONS

The Problem

The fading of dyes through chemical reactions with acid substances has been a problem of economic importance to consumers, retailers, dry-cleaners and textile manufacturers for a number of years. Precautionary measurers have been taken by using acid resistant dyes or by inhibiting acid sensitive colors against fading or color change. These measurers have lessened the problem of color change to some extent, but colorfastness of dyed fabrics continues to be a subject of considerable research in the textile industry.

This study was designed to serve as a basis for continued research in the area of colorfastness to perspiration, antiperspirants and atmospheric fumes. The purposes of the study were:

1. To test the color sensitivity of selected fabrics to perspiration, antiperspirants and a combination of these two factors.
2. To determine the effects of the oxides of nitrogen on selected fabrics treated with perspiration and antiperspirants.

Procedure

The selection of the acetate fabrics for this study was made under the direction of textile research personnel. The acetate fabrics were specially prepared with known dyeings in order to control unknown variation of dyes. One group of three acetate fabrics was dyed with Class A dyes which are designated as being fast to light, acid and fumes. Another group of three acetate fabrics was dyed with Class B dyes which are designated as being subject to color change particularly when exposed to fumes and are also likely to be affected by acid-base changes. One of the Class B dyed fabrics was treated with chemicals which are used commercially to prevent fume fading. One dyeing of this fabric was finished with a fugitive inhibitor, a 10 per cent solution of triethanolamine. One dyeing was finished with a substantive inhibitor, Permalene AF (diphenylethylenediamine).

The non-acetate fabrics which were used in this study included fabrics of varied fiber content that were of known dye types. The non-acetate fabrics were representative of some of the fabrics that are available for commercial use. The dye types which were used on the non-acetate fabrics represented those dye types which are currently being used in manufacturing textile goods for consumer use.

The stain solutions which were used in the study included: distilled water, acid perspiration, alkaline perspiration and three solutions of antiperspirants.

Distilled water was used as a control solution in the study in order to determine the effect of moisture on the colors of fabrics.

The two solutions of perspiration were made up according to the specifications in the American Association of Textile Chemists and Colorists Standard Test Procedure for Testing Colorfastness to Perspiration.

Three solutions which are used in the formulation of many anti-perspirants and deodorants were used to represent the number of such products which are available to consumers. The antiperspirant solutions used were:

1. Aluminum Sulfate, 10 per cent concentration, pH adjusted to 3.2 with Sodium Hydroxide.

2. Aluminum Chlorohydroxide, 10 per cent solution, pH adjusted to 4.2.

3. Aluminum Chloride, 25 per cent aqueous solution buffered, pH adjusted to 4.2.

<u>Application of Solutions</u>

One half of an area of fabric large enough to permit two replicates was marked off into twelve segments. Two drops of each antiperspirant solution were applied to the areas designated by a table of random numbers. This random application was used to prevent a systematic order of application which might bias the judgements of color change. When these solutions were absorbed, two additional drops of the antiperspirant solutions were applied to the same areas. The test fabrics were dried for 15 minutes at 38^{o} C. Following the drying period four drops of the perspiration solutions were applied to the areas specified. The samples were then dried at 38^{o} C for six hours. Before being judged for color change, the samples were immersed in perchlorethylene for three minutes and air dried.

All color changes were evaluated by three judges, and the procedure for evaluation was based on the International Geometric Grey Scale.

Class 5, no appreciable change in shade
Class 4, slight change in shade
Class 3, noticeable change in shade
Class 2, considerable change in shade
Class 1, severe change in shade

Findings Pertaining to the Effects of the Stain Test Solutions on the Colors of the Selected Fabrics

As a result of this study it was found that acid substances such as perspiration and antiperspirants did cause color changes in some of the fabrics selected for the study. Combinations of these substances resulted in greater color change than when used alone.

Moisture in the form of distilled water (used in making all solutions) caused no color change on any of the fabrics used in the study. The acid nor alkaline perspiration solutions caused no appreciable color changes on any of the fabrics used in the study.

The antiperspirant solutions caused more evidence of color change and varied in their effect on the colors in the different fabric groups.

Aluminum sulfate produced slight color changes on:

1. Class A Dyed Acetates
2. Class B Dyed Acetates
3. Substantively inhibited acetate
4. Some of the non-acetate fabrics (chemical deposits on the others)

This antiperspirant caused considerable color change on the acetate fabric which was finished with the fugitive inhibitor.

Aluminum chlorohydroxide produced slight color changes on:

1. Class A Dyed Acetates
2. Class B Dyed Acetates

Noticeable changes were noted on the:

1. Substantively inhibited acetate
2. Non-acetate fabrics

Considerable color change was apparent on the fugitively inhibited acetate.

Aluminum chloride produced noticeable color changes on:

1. Class A Dyed Acetates
2. Class B Dyed Acetates
3. Substantively inhibited acetate
4. Some of the non-acetate fabrics (chemical deposits on the others)

The combinations of acid perspiration with each of the anti-perspirants varied in their effects on the colors in the different fabric groups.

Acid perspiration and aluminum sulfate caused slight color changes on:

1. Class A Dyed Acetates
2. Class B Dyed Acetates
3. Substantively inhibited acetate fabric

This combination produced noticeable color change and chemical deposits on the non-acetate fabrics and a considerable color change in the fugitively inhibited fabric.

Acid perspiration and aluminum chlorohydroxide caused slight color changes on:

1. Class A Dyed Acetates
2. Class B Dyed Acetates
3. Substantively inhibited acetate fabrics

This combination produced noticeable change on the non-acetate fabrics and a severe color change on the fugitively inhibited acetate fabric.

Acid perspiration and aluminum chloride caused a slight color change on the Class A dyed fabrics. This combination caused noticeable color changes on:

1. Class B Dyed Fabrics
2. Substantively inhibited acetate fabric
3. Some of the Non-Acetate Fabrics (Chemical deposits on others)

There was no appreciable color change on the fugitively inhibited acetate fabric, however there was a severe chemical deposit.

The combinations of alkaline perspiration with each of the anti-perspirants also varied in their effects on the colors in the different fabric groups.

Alkaline perspiration and aluminum sulfate caused slight color changes on:

1. Class A Dyed Acetates
2. Class B Dyed Acetates
3. Substantively inhibited acetate
4. Some of the non-acetate fabrics (Chemical deposits on others)

This combination caused a considerable color change on the fugitively inhibited acetate fabric.

Alkaline perspiration and aluminum chlorohydroxide caused slight color changes on:

1. Class B Dyed Acetates
2. Substantively inhibited acetate fabric
3. Some of the non-acetate fabrics (Chemical deposits on others)

This combination caused noticeable color changes on the Class A dyed acetate fabrics and a considerable color change on the fugitively inhibited fabric.

Alkaline perspiration and aluminum chloride caused noticeable color changes on:

1. Class A Dyed Acetates
2. Class B Dyed Acetates
3. Substantively inhibited acetate fabric
4. Some of the non-acetates (Chemical deposits on others)

This combination caused a chemical deposit on the fugitively inhibited acetate fabric.

Findings Pertaining to the Effects of the Fumes on the Colors of the Selected Fabrics

The test specimens to which the solutions of perspiration and antiperspirants had been applied were cut in half. One half of the sample which was to be exposed to the fumes was attached to a strip of white muslin and suspended in the fume fading chamber for one exposure period. The half which had been exposed was then compared to the unexposed half and the judges were instructed to classify color changes in the following way:

Class 3, no noticeable change in shade

Class 2, slightly noticeable change in shade

Class 1, considerable change in shade

Differences between the stained areas of the exposed and unexposed fabrics were noted. The effect of the fumes varied according to the stain and fabric group.

The majority of the exposed fabrics treated with water, acid perspiration and alkaline perspiration showed no noticeable change in color from the unexposed fabrics. Slight changes were noted on the Class B dyed fabrics treated with the three solutions and on the fugitively inhibited fabric stained with water.

The exposed fabrics treated with antiperspirants showed more evidences of difference than the exposed fabrics treated with perspiration. Slight differences were recorded for:

1. Class B dyed fabrics stained with each of the antiperspirants.
2. Class A dyed fabrics stained with aluminum sulfate
3. Non-acetate fabrics stained with aluminum chloride

Considerable differences were recorded for:

1. Substantively inhibited acetate fabric treated with aluminum sulfate
2. Fugitively inhibited acetate fabric treated with aluminum sulfate

The exposed fabrics which were treated with acid perspiration combined with each of the antiperspirants showed more evidences of differences than the exposed fabrics which were treated with antiperspirants alone.

Slight differences were noted on:

1. Class A dyed acetates treated with acid perspiration and aluminum chlorohydroxide
2. Class B dyed acetates treated with acid perspiration and each of the antiperspirants
3. Non-acetate fabrics treated with acid perspiration and aluminum chloride

Considerable differences were noted on both of the inhibited fabrics treated with acid perspiration and each of the antiperspirants.

Except for Class A dyes, differences were also noted on the fabrics treated with alkaline perspiration combined with each of the antiperspirants.

Slight differences were noted on:

1. Class B dyed acetates treated with alkaline perspiration combined with each of the antiperspirants
2. Non-acetate fabrics treated with alkaline perspiration combined with aluminum sulfate and with aluminum chlorohydroxide

Considerable differences were noted on both of the inhibited fabrics treated with the combinations of alkaline perspiration with each of the antiperspirants.

Conclusions

1. The colors in all fabrics used in the study maintained excellent resistance to the perspiration solutions.

2. There was more evidence of color change in fabrics treated with the antiperspirant solutions and the combinations of perspiration with the antiperspirants.

   The antiperspirant solutions and combinations of perspiration and antiperspirant solutions tended to affect colors adversely even though many were supposedly colorfast to acids. Colors in only three of the fabrics selected for the study were consistently resistant to color change. These were the two yellow acetate fabrics (C and F) and the wool and Dacron fabric of the non-acetate group.

3. When considered as groups, the Class A and Class B acetate fabrics did not differ greatly in their response to perspiration, antiperspirants or to combinations of perspiration and antiperspirants.

4. The inhibitors applied to the blue acetate fabric differed in resistance to the stains.

   The substantively inhibited fabric differed little from the fabric which was finished neutral. The fabric which was finished with the fugitive inhibitor was more sensitive to the stain test solutions.

5. The differences between the ratings of the acetate fabrics and non-acetate fabrics indicated that the colors of the non-acetate fabrics were more affected by the antiperspirant solutions and by combinations of perspiration and antiperspirant solutions than the acetate fabrics. These lower ratings could, in many cases, be attributed to chemical deposits rather than to changes in hue or shade.

6. The fumes slightly affected the background areas of the Class A dyed fabric A and the Class B dyed fabrics D_1 and E. The background area of the substantively inhibited fabric D_3 was slightly affected by the fumes. The background area of the fugitively inhibited fabric was considerably affected by the fumes. The background areas of all the non-acetate fabrics were unaffected by the fumes.
7. The stained areas of the Class B dyed fabrics were more affected by fumes than were the stained areas of the Class A dyed fabrics. This was true for all applied.
8. Stained areas of both test pieces of the blue acetate fabric finished with inhibitors showed evidences of fume fading. Both substantive and fugitive inhibitors lost their effectiveness when treated with aluminum sulfate and with combinations of both perspiration solutions with the antiperspirants.
9. The stained non-acetate fabrics were more resistant to fume fading than the Class B dyed acetate fabrics. While there were some evidences of fume fading on individual fabrics, the group showed fastness similar to the Class A dyed acetate fabrics.

Recommendations for Further Study

It is recommended that the study be continued by investigating further the sensitivity of fabrics to acid conditions. Specific areas suggested for investigation are:

1. The effect of the perspiration and antiperspirant solutions

on fabrics of more carefully selected fiber content specially prepared with acid sensitive dyes selected from shade cards of dye manufacturers.

2. To investigate the effects of commercial preparations of antiperspirants on the colors of the specially prepared fabrics.

3. To investigate the effects of fumes (more than one exposure) on the colors of the specially dyed fabrics which have been stained with commercial antiperspirants.

4. To expose fabrics which have been treated with antiperspirants to combustion gases enriched by generated oxides of nitrogen (phosphoric acid plus a dilute solution of sodium nitrite) at high humidity.

It is further recommended that test specimens be sufficient size to substitute the use of objective methods of measuring color changes for the subjective methods which were used in this study.

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APPENDIX

APPENDIX A

RANDOM ORDER OF APPLICATION OF STAIN SOLUTIONS
(Acetate Fabrics)

Solutions	Fabrics: A Replicates I	A II	B Replicates I	B II	C Replicates I	C II	D 1 Replicates I	D 1 II	D 2 Replicates I	D 2 II	D 3 Replicates I	D 3 II	E Replicates I	E II	F Replicates I	F II
Distilled water	8	9	1	11	5	9	3	9	11	12	5	6	2	5	12	5
Acid perspiration	1	6	3	9	10	2	7	12	6	6	8	11	7	8	5	8
Alkaline perspiration	7	7	10	7	3	7	2	8	2	8	4	1	1	3	6	6
Aluminum sulfate	4	12	9	8	1	3	12	10	8	5	1	7	5	12	2	10
Aluminum chlorohydroxide	3	4	6	10	6	10	11	7	9	10	9	9	6	11	7	7
Aluminum chloride	11	3	2	5	8	11	8	6	3	1	12	12	3	2	4	1
Acid perspiration plus aluminum sulfate	5	8	12	12	9	4	6	5	12	2	2	2	8	1	10	2
Acid perspiration plus aluminum chlorohydroxide	6	10	8	2	4	5	1	4	10	9	6	8	9	9	1	3
Acid perspiration plus aluminum chloride	2	5	11	1	7	8	9	11	7	4	7	4	4	4	11	9
Alkaline perspiration plus aluminum sulfate	10	2	7	6	2	6	10	3	5	11	10	5	12	10	3	12
Alkaline perspiration plus aluminum chlorohydroxide	9	1	4	3	12	12	5	1	4	3	3	3	11	6	9	4
Alkaline perspiration plus aluminum chloride	12	11	5	4	11	1	4	2	1	7	11	10	10	7	8	11

APPENDIX A (Continued)

RANDOM ORDER OF APPLICATION OF STAIN SOLUTIONS

(Acetate Fabrics)

Solutions	G Replicates I	G Replicates II	H Replicates I	H Replicates II	I Replicates I	I Replicates II	J Replicates I	J Replicates II	K Replicates I	K Replicates II	L Replicates I	L Replicates II
Distilled water	11	6	11	6	7	6	11	7	1	3	9	8
Acid perspiration	2	1	10	11	9	10	12	6	6	10	1	4
Alkaline perspiration	10	2	7	10	4	7	4	2	9	12	6	1
Aluminum sulfate	9	7	5	4	12	2	9	11	5	7	4	10
Aluminum chlorohydroxide	8	3	2	9	2	12	5	10	12	5	2	6
Aluminum chloride	7	5	3	2	5	1	6	12	2	8	7	2
Acid perspiration plus aluminum sulfate	4	10	8	7	1	11	3	8	4	1	5	7
Acid perspiration plus aluminum chlorohydroxide	12	4	4	3	3	9	8	5	8	6	3	5
Acid perspiration plus aluminum chloride	5	8	12	1	10	4	2	3	3	2	11	11
Alkaline perspiration plus aluminum sulfate	6	9	9	5	6	8	7	9	7	11	8	9
Alkaline perspiration plus aluminum chlorohydroxide	3	11	1	12	11	5	10	1	11	4	10	12
Alkaline perspiration plus aluminum chloride	1	12	6	8	8	3	1	4	10	9	12	3

Appendix B

Judge Number ______

Fabric	Fabric	Fabric	Fabric
Date	Date	Date	Date

Area	Rating	Rating	Rating	Rating
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				