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THE EFFECT OF CARRIERS ON THE FLAMMABILITY OF POLYESTER AND TRIACETATE

by

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B. S., Kansas State University, 1978

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles, and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1980

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ACKNOWLEDGEMENTS

This thesis would not have been possible without the combined efforts of several individuals. In particular, I would like to express my gratitude to my major professor, Dr. Barabara Reagan, for her technical assistance and for giving me the necessary motivation and enthusiasm for my chosen area of study. A special thanks goes to the following companies for donating the carriers which were evaluated in this study: Arkansas Chemical Company, Tanatex, Chemical Processing of Georgia, Hart Products Corp., and Sandoz Colors & Chemicals. I would also like to thank Dr. Elizabeth McCullough and Dr. Arlin Feyerherm for their helpful discussion and constructive criticism of this work. Others who have helped make this study possible are: Mary Elling, for her statistical analysis of my data; Dr. Randy Bresee, for his technical and mechanical assistance in the laboratory; my parents, Mr. and Mrs. Lawrence Streit, for instilling in me the values of an education; and finally Scott, who has been a constant source of encouragement and understanding throughput my graduate study.

INTRODUCTION

Synthetic fiber production has increased at a phenomenal rate over the past ten years. Polyester fiber production, for example, has increased at an average rate of 22% per year for the past 10 years and is projected to climb close to 6½% per year throughout the final quarter of this century (22). Today, polyester is probably the most important fiber used by the textile industry, particularly in apparel applications (23).

The growth of synthetic fibers such as polyester and triacetate did not proceed without its problems, though. Polyester's outstanding properties of strength and light resistance were quickly recognized, but when it was first developed it was virtually undyeable. When first introduced, triacetate was a failure due to its dyeing difficulties. As new techniques for dyeing polyester and triacetate were developed, dyeing became much more practical. The first important development was the use of carriers, such as ortho-phenyl phenol, which increased the uptake rate of disperse dyes, followed by the commercial use of high temperature dyeing under super-atmospheric pressure in closed vessels (31). Another major development which was introduced by E. I. du Pont de Nemours was the thermosol dyeing process for dyeing both 100% polyester and polyester blends (i.e., cotton/polyester).

These new developments were responsible for the widespread use and acceptance of polyester and triacetate. By 1973, polyester had captured 40% of the total U. S. wearing-apparel fiber market and accounted for 68% of the synthetic fibers used in apparel (24).

Since polyester and triacetate are used so extensively in apparel, its flammability characteristics are of importance. Several studies have indicated that many dyes used on polyester can significantly influence the flammability characteristics of the fiber or fabric (3, 23). The flammability of textiles is known to depend on the chemical composition of the fiber, the geometric structure of the yarn and fabric, finishes, dyes, impurities, and auxiliaries used in wet processing. (32).

Carriers, auxiliaries used to promote the dyeing of polyester and triacetate, are often toxic, highly volatile, and flammable. These products are frequently found to be insoluble in aqueous solutions and are difficult to remove from the fabric. Removal often requires washing in temperatures near the boil. Theoritically, these dye auxiliaries are removed from the fabric during the afterwash. It is questionable whether carriers are actually removed from the fabric using these procedures, especially with new methods being considered in dyeing and finishing operations to reduce energy and water consumption. This leads to the question, if traces of carriers are still present in the fabric, will the carrier affect the flammability of the fabric? The purpose of this study was to determine the effect of carriers on the flammability of polyester and triacetate. The effects of different concentration levels of carriers on the fabric and how they relate to the flammability of the fabric also was investigated.

REVIEW OF LITERATURE

Dyeing Polyester

Regular polyester fibers are hard to dye because, unlike synthetic polyamide fibers and the natural fibers, they contain no ionic groups. Thus, they cannot be dyed by the ionic mechanism used for the other fibers using direct, acid, and basic dyes. Regular polyester is mainly dyed with disperse dyes which are nonionic in character. Even with disperse dyes, there are dyeing difficulities due to the slow rate of diffusion of the dye through the polymer.

There are other types of polyester which are easier to dye, however. The two main types are carrierless dyeable polyester and cationic dyeable polyester. Carrierless dyeable polyester can be made by incorporating amino groups into the polymer chain. This group gives the fiber increased affinity for acid dyes. Generally, the properties of carrierless dyeable polyester are not as good as that of regular polyester. They have lower strength, poorer wash and light fastness, and the dye molecules are not as uniformily absorbed resulting in some penetration problems (33).

Cationic dyeable polyester is formed by incorporating sulphonic acid groups into the polymer. The sulphonic end group results in the increased affinity for basic dyes. Generally, aromatic sulphonic acid groups are used so as not to alter the regularity of the polymer chain thereby maintaining existing fiber properties (33).

Successful dyeing of polyester can only occur through the application of energy to the fiber/water/dye system. The energy can be applied in the form of heat or chemical energy. For dyeing to take place, the disperse dye must be transferred to the surface of the polyester fiber and then diffuse into the interior of the fiber. For satisfactory fastness, the dye must be held in the interior of the fiber. Because of the high crystallinity and rigid structure of the polyester fiber and the size of the disperse dye molucules, diffusion of the dye molecules can only take place if the molecular chains move apart and permit the dye molecule to position themselves in between the polymer chains. Dye uptake is facilitated by dyeing at temepratures above the boil or by using a solvent which is commonly referred to as the dye carrier. Until recently, carrier dyeing has been the preferred method of dyeing polyester. At the present time, there is a shift toward to use of high temperature dyeing methods. In order to achieve satisfactory dye diffusion without the use of a carrier, temperatures in the range of 125 to 140^{0} C are required.

Adequate penetration of the dye, however, is not the only requirement for a successful dyeing. Polyester and triacetate fibers are produced by a process involving polymerization, spinning, drawing, and texturizing which produces significant variations in molecular and morphological structures of fibers from different batches of polymer and even along the length of fibers from the same batch. These variations result in differences in the ability of specific fibers, or portions of the fiber to accept the dyes. The resulting depth of dyeing can therefore be unequal on different fibers or on different portions of the same fiber. To prevent an uneven or blotchy appearance, the dye must be transferred from areas of high dye concentration to areas of low dye concentration until a fairly uniform level of dyeing over the entire substrate is achieved. The carrier, to some extent, accomplishes some of the leveling, but a much greater degree is carried out by the use of migrating agents.

Carriers

A dye carrier may be described as a solvent that can penetrate the polyester fiber allowing the dye to diffuse into the fiber and take up a permanent position between the polymer chains (10). Most commercial carriers have two components, an active substance which is more or less water soluble, and a dispersing or emulsifying agent to produce pseudo-water solubility of the active substance (28). Most effective dye carriers are aromatic organic compounds. Some of the common active ingredients used in carriers include o-phenyl phenol, methyl salicylate, methyl naphthalene, diphenyl oxide, butyl benzoate, 1,2,4-trichlorobenzene, biphenyl, and methyl benzoate. Regardless of the process used, most of the above active ingredients are not as effective if used by themselves. Most of them are water insoluble and must be present in the dye bath in emulsion form to be useful in the process (10).

Commercial carriers are emulsified formulations of the active chemical substance which produces a stable product having the required emulsion and activity properties. In formulating carriers, it is important to select emulsifying agents that do not separate from the carrier globules during dyeing. If this occurs, large droplets of the active carrier will be formed, which deposit on the material and give rise to carrier stains resulting in more dye being absorbed in the stained areas (26).

The concentration of the active component may vary from 10 to 90% in commercially prepared carriers (10). The concentration may vary depending upon the type of active substance and the intended end use for the carrier. Often times other chemicals are added which impart specific properties, such as stabilizers, defoamers, lubricants, and leveling agents. Carriers are formulated in both liquid and powder forms. The majority of the carriers used in polyester dyeing are available in liquid form and only a few are available as white powders (27).

The suitability of a substance as a carrier depends upon many properties. Some of these properties include price, odor, toxicity, biodegradability, volatility, compatibility with dyes, dispersion stability, and influence on light-fastness and fiber shrinkage. Since the importance of these properties vary widely, an overall rating for a carrier is nearly impossible (5).

Usage of Carriers

Biphenyl, o-phenyl phenol, and methyl naphthalene are the strongest of the carrier active chemicals. Their use is dictated for relatively low temperatures, such as those encountered in atmospheric dyeing. Of the three, biphenyl has the best combination of strength and migrating action and is followed by methyl naphthalene. O-phenyl phenol has very poor migrating ability and requires large amounts of migrating agent when used as the sole active ingredient (10).

Trichlorobenzene and diphenyl oxide as a group are the next highest in strength properties. They are most effective when used at the elevated temperatures found in pressure dyeing although they can be used in many applications under atmospheric conditions at higher concentrations. Of the two, trichlorobenzene has very high migrating ability and is especially useful as a repair carrier where the leveling and stripping of uneven dyeings is necessary (10).

Butyl benzoate and methyl biphenyl are the weakest compounds and their use is limited to pressure dyeing. Because of the excellent migrating properties of butyl benzoate, it is the preferred carrier for use in package dyeing of polyester yarn where achievement of level dyeing is very difficult. Methyl benzoate has properties similar to butyl benzoate, but a higher volatility resulting in its limited use of pressure dyeing (10).

Estimated sales volumes of the active ingredients used in carriers can be determined but is difficult to figure because of the varying concentration in the commercially prepared carriers. Based on usage by the Tanatex Chemical Company, an estimate of the volume of carrier chemicals used in the United States is shown in Table 1 (10).

Table 1
Usage of Carrier Chemicals

Active Ingredient	MM lb/year
Biphenyl	15
Butyl Benzoate	4
Trichlorobenzene	6
Methyl Benzoate	5
Methyl Cresotinate	0.4

Selection and Functions of Carriers

In selecting the proper type and amount of carrier, since no single carrier appears to be universally acceptable, consideration must be given to the foaming properties of the carrier, the type of dye, the dyeing equipment, and the dyeing temperature (12). Also important in determining the proper amount of carrier to be used is the desired depth of dyeing. An inadequate amount of carrier results in poor build-up and nonuniform dyeing. The presence of an excessive amount can cause the desorption of dyes and a decrease in the tensile strength of the fabric. The continuing presence of carrier in the dyebath or fiber is essential for good dye exhaustion. Carriers that are readily lost through volatilisation have a short period of effectiveness (26). In application of the carrier, the higher the liquor ratio, the more carrier left in the bath (5).

It is felt that carriers serve three functions: 1) to promote dye yield, 2) to promote leveling, and 3) to minimize dye-rate differences between yarns. At best, a carrier will excel in only one or two of these three areas (15).

The Carrier Mechanism

The exact mechanism by which carriers increase the dye uptake is not known. Numerous theories have been explored to explain the carrier mechanism. The transport theory proposes the formulation of a loose complex between dye and carrier. The spectrophotometric analysis of dye-carrier systems and the absence of suitable reactive groups in many carriers have tended to disprove this theory. A second theory supports the premise that the carrier increases the solubility of the dye in the liquor and, hence, the rate of dyeing. The particle entering the fiber is either a dye-carrier complex, which is smaller than the dye aggregate, or the dye-carrier complex releases dye molecules into the fiber (17). This theory has been disproved, however, by studies with tri-propylphosphate (7). This increase in aqueous solubility of the dye carrier is considered a secondary phenomenon. The film theory speculates that carriers form a film around the fiber and the dye dissolves in the carrier. The dye is then more easily transported into the interior of the fiber. This theory has been supported by the presence of droplets of carrier on the surface (6), and a carrier film 100 Å thick over the fiber surface has also been reported (7). A fourth theory, the increased water imbibition theory, proposes that the aromatic portion of the carrier molecule is associated with the hydrophobic fiber by van der Waal forces. The hydrophilic portion of the carrier attracts water and gives an increased flow of dye liquor into the fiber. However, many carriers such as trichlorobenzene and diphenyl oxide have no hydrophilic groups. The increased swelling theory is exhibited by the phenolic compounds, such as o-phenyl phenol. It is suggested that carriers cause the fibers to swell, allowing larger molecules to penetrate the fiber. Several studies have shown that a wide range of carriers can cause swelling and the swelling may be important, but there does not seem to exist a direct relationship between the swelling power and the carrier activity (7). Another study has also been carried out indicating that the increase in the rate of dyeing caused by a carrier is not necessarily accompanied by fiber swelling (21). Another theory postulates that the carrier causes an increase in the number of dye sites. That is, the carrier opens up the structure and increases the number of available sites for the dye (17). In the molecular lubrication theory, it is believed that the carrier acts as a lubricating agent, thereby increasing the plasticity of the polymer chain making the chains more mobile so the dye can penetrate (19, 20, 25).

The most widely believed and accepted theory is the one which supports the premise that the carrier loosens the fiber structure. It is believed that the carrier is adsorbed by the fiber in a similar manner to that of disperse dyes, but because the carrier is smaller in size, it diffuses more readily. The interchain bonds are replaced by weaker fiber-carrier bonds which loosens the fiber's microstructure and allows the dye to more readily enter the fiber. Since the microstructure of the fiber is changed, the glass transition temperature is lowered. The increase in the rate of dyeing and the decrease in the glass transition temperature are related to the quantity of carrier in the fiber. The chemical structure of the carrier seems to be of less importance as long as it is absorbed by the fiber (5).

Most practical dyers believe that carriers are dye-specific in action, but since the rate effect is exerted on the fiber and not by interaction with the dye, one might expect similar rate effects for all dyes (5).

Environmental Properties

The possibility exists that the use of carriers in dyeing could be curtailed due to the Federal Water Pollution Control Act (14). The most effective approach to protecting our health and environment from damage due to chemicals is to combine good scientific data about the chemicals with suitable handling and disposal practices.

The environmental data on carriers is incomplete and contradictory (13, 30). Frequently, toxicity and biodegradability are the soul criteria used in evaluating the environemntal impact of a compound. Rather, a combination of interacting physical, chemical, and biological properties should be used to form the basis for assessing the effects of a compound on the environment. Four key parameters include movement, degradation, bioconcentration, and toxicity (30).

Dye carriers may be released to the environment through atmospheric or water discharges. The loss of dye carriers to the environment has been reduced significantly in the past few years. Available data for biphenyl, methyl biphenyl, diphenyl oxide, and 1,2,4-trichlorobenzene indicate very low water solubilities and rapid movement from water to air. Half-lives of most dye carriers in a well mixed body of water about one meter deep range from 6 to 8 hours. An exception to this is o-phenyl phenol whose half-life is about 20 hours because of its greater water solubility (30).

Degradation of dye carriers through the reaction with chemicals, such as oxygen and water, is very slow. It has been shown that mon- and dichlorobenzenes are persistent enough to become water pollutants after passing through quiescent or aerated lagoons (13). The stability of dye carriers to photodegradation is important in determining the environmental persistance of these compounds which often move into the air. The most likely route carriers will exit from the environment is shown in Figure 1.

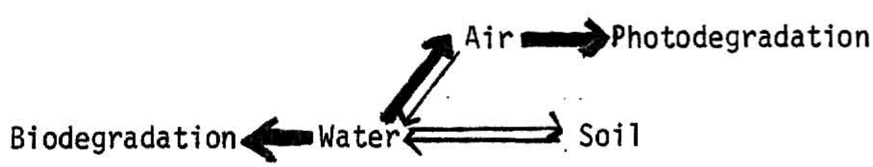


Figure 1: Exit of Carriers From the Environment

Since carriers are generally aromatic compounds and contain various percentages of hydrogen, they are susceptible to photodegradation. The carriers half-life in the atmosphere may vary from a few days to a few weeks depending upon the structure of the carrier (30).

Biodegradation is another important exit for dye carriers. Available data indicates that biphenyl, 1,2,4-trichlorobenzene, diphenyl oxide, methyl biphenyl, and o-phenyl phenol are all biodegradable. These carriers all have BOD values of greater than 50% in 10 days and greater than 75% in 20 days, indicating their ability to degrade in receiving waters (29, 30).

Biphenyl, methyl biphenyl, 1,2,4-trichlorobenzene, diphenyl oxide, and o-phenyl phenol exhibit similar toxicological hazards to aquatic organisms and the release of large amounts of them into natural bodies of water should be avoided (30). The potential hazard of carriers to man should be considered in terms of type of exposure and length of exposure most likely to occur, as well as the overall biological activity.

Toxicity testing on mammalian species have shown that biphenyl, methyl biphenyl, diphenyl oxide, 1,2,4-trichlorobenzene, and o-phenyl phenol possess similar hazards because of acute ingestion and skin irritations. Biphenyl and o-phenyl phenol are also known to cause eye irritation and damage (30).

Vapor inhalation offers the most significant hazard to workers handling dye carriers because all of them produce irritating fumes or dust. The suggested threshold limit for most carriers is below 5 ppm's. Biphenyl's are particularly vulnerable, though, since a 0.2 ppm threshold limit value (TLV) has been set for it and it is difficult to acheive this in atmospheric dyeing without the use of expensive ventilation equipment (10). Adequate ventilation should be provided during the use of all dye carriers to maintain air concentrations below the TLV.

All chemicals, if misused, can cause environmental problems. The main key here is to avoid misuse. Procedures that can be used to optimize removal of carriers during treatment are acclimation and continuous exposure of degrading microorganisms to the chemicals, adequate aeration, and optimum flow rates (30).

The tendency today is to change from chemical to thermal energy to dye polyester and triacetate for environmental reasons. However, in the midst of a critical energy shortage, there is little doubt that the tendency will be reversed, that is, carriers will be used more extensively again (10).

Removal of Carriers

Because of their toxicity, carriers should be completely removed from the fabric after dyeing. The rate of carrier removal during finishing may depend on the diffusion rate in the fiber, the desorption rate, and the ability of the environment to absorb the carrier. As the carrier is removed during finishing, the diffusion rate may be affected several ways, one by altering the concentration gradient and the other by changing the glass transition temperature. Generally, carrier removal is carried out by a high temperature scour near the boil or by passage of the fabric, while on a tenter frame, through a heat-setting unit. If a scouring procedure is used, the temperature of the scouring bath is very important. Studies have shown that a low temperature scour is ineffective in reducing the carrier content on the fabric (16). For efficient carrier removal, it is necessary to treat the fabric at a temperature above its glass transition temperature (16).

Incomplete removal of the carrier can often cause skin irritations and reduce the lightfastness of the dye (8). Azo disperse dyes and anthraquinone dyes, in general, are affected by residual carrier. The fastness is generally lowered ½ to 1 point on the Gray Scale in comparison to that of high-temperature dyeings carried out with the same dye formulation (26).

Flammability

Raw polyester fibers as shipped by the fiber manufacturer, have an inherent ability to resist ignition by melting and curling away from the flame. Triacetate, on the other hand, burns readily forming a hard black bead. Since these fibers are used widely in apparel, the fabrics made from them must pass the standard set-up by the Flammable Fabrics Act for apparel, that is, CS 191-53, Flammability of Clothing Textiles (11). The test instrument specified in the standard is the 45^{0} Angle Flammability Tester. For fabrics to pass the standard, they must not spread flame up the length of the sample in less than 3.5 seconds for smooth fabrics and 4.0 seconds for napped fabrics.

Another tool for evaluating the flammability of polymers, such as polyester and triacetate, is the Oxygen Index Flammability Tester. This instrument measures the minimum amount of oxygen needed to just support combustion in a mixture of nitrogen and oxygen under conditions of candle-like burning. This test instrument provides a valuable tool for the investigation of flammability as a function of the chemical composition of the textile substrate (32).

Carriers are often very flammable compounds which leads one to question the flammability of fabrics which have been treated with carriers, especially when they are not completely removed from the fabric after dyeing. The ease in which carriers are removed from the fabric is an important factor in predicting the fabrics flammability just as is the chemical type of the specific carrier (9). The free rinsing properties of a carrier are often determined by the carrier's emulsification system. It is known that samll amounts of residual waxes or oils can have a significant effect on the flammability of a fabric. Long scouring times of 30 minutes and high temperatures (85^{0} C) are needed to reduce the residual contaminants to a level having no effect on flammability (18).

In a study carried out by Holmes (18), five carriers were applied to a FR Arnel triacetate/polyester blend and then tested for their effects on flammability using the Children's Sleepwear Standard, DOC FF 3-71. The results showed that all of the carriers had a slight deleterious effect on flammability and should be used at minimum effective concentrations. The study further suggested that for fabrics dyed with the use of carrier, the best flammability properties could be obtained after a thorough afterwash and a heat treatment to remove the residual carrier (18).

Significance of Study and Objectives

Carrier removal presents a problem to dyers and finishers since it is necessary to cut back on water and energy consumption. Therefore, it is necessary to assess the problems that might arise if carrier removal is incomplete. It is known that carriers are toxic and can cause skin irritations. Some work has been done in the area of carrier flammability, but the degree to which carriers actually increase or decrease the flammability of polyester and triacetate has not been thoroughly explored. Thus, the purpose of this study was to evaluate the effects of seven commercially available carriers on the flammability of polyester and triacetate by using the Oxygen Index Flammability Tester which measures the percentage of oxygen required to support combustion, and the 45^{0} Angle Flammability Tester which measures flame spread times.

Specific objectives of this study were:

1. To determine if various carriers significantly alter the oxygen index values and flame spread times of regular polyester and triacetate.
2. To determine if various concentration levels of carriers significantly alter the oxygen index values and flame spread times of regular polyester and triacetate.
3. To determine if various carriers have a greater effect than others on the oxygen index values and flame spread times of polyester and triacetate.

PLAN OF PROCEDURE

The purpose of this study was to determine if carriers affect the flammability of polyester and triacetate fabrics. The carriers were applied to the fabric using a mock dyeing procedure at concentration levels of 0.0, 1.0, 5.0, and 15.0% owf. The fabrics were then evaluated for flammability by using the Oxygen Index Flammability Tester (OI) and the 45° Angle Flammability Tester.

Experimental Fabrics

The following fabrics used in this study were obtained from Testfabrics Inc:

1. 100% spun Dacron 54 polyester, plain weave with a 39 X 34 thread count (Style #755).
2. 100% spun Arnel triacetate, plain weave with a 41 X 34 thread count (Style #120).

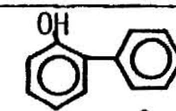
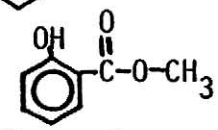
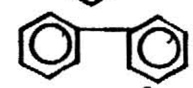
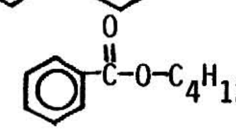
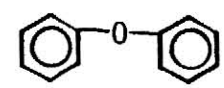
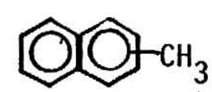
The fabrics were washed prior to testing in AATCC Detergent 124 using washing and drying procedures IIB in AATCC Test Method 124-1978, Appearance of Durable Press Fabrics After Repeated Home Launderings (1). The pre-wash was necessary to remove any residual waxes or oils left on the fabric from weaving which may have adversely affected the flammability. After scouring, the fabrics were cut into samples measuring 55.9 X 30.5 cm and weighed to the nearest 0.01 g. The edges of the samples were finished with a zig-zag stitch to prevent raveling during subsequent treatment.

Carriers

The tradenames, manufacturers, and chemical composition of the seven carriers evaluated in this study are presented in Table 2.

Table 2

Carriers Evaluated

Code	Commercial Name	Manufacturer	Chemical Name	Chemical Formula
A	Anthrapole 73	Arkansas Chemical Company	o-phenyl phenol	
B	Anthrapole ND	Arkansas Chemical Company	methyl salicylate	
C	Carolid AL	Tanatex	biphenyl	
D	Chemcryl C-101-N	Chemical Processing of Georgia	butyl benzoate	
E	Chemcryl JK-EB	Chemical Processing of Georgia	diphenyl oxide	
F	Dycar MN	Hart Products Corp.	methyl naphthalene	
G	Dilatin PT	Sandoz Colors & Chemicals	perchloroethylene	$Cl_2C=CCl_2$

Carrier selection was based in effectiveness, availability, and commercial importance (7, 12, 28).

The carriers were applied to randomly selected samples at concentrations of 0.0, 1.0, 5.0, and 15.0% owf. The carrier bath was made-up by adding the proper amount of a 1.0% stock solution of the carrier to a beaker and then adding enough distilled water to bring the solution to volume for a 30:1 liquor-to-goods ratio. The pH of the solution was adjusted to 5.0 to 5.5 with acetic acid. The carrier solution was placed in the Launder-Ometer canisters and the fabric, previously wet-out in distilled water, was added to the solution. The canisters were sealed and loaded into the Atlas Launder-Ometer set at 80^{o} C. The temperature was raised to just below the boil (99^{o} C) during the first 10 minutes and held at this temperature for 60 minutes. At the end of the 60 minutes, the canisters were removed and cooled in a water bath. The samples were then removed from the canisters, rinsed in distilled water (25^{o} C) for one minute, air dryed, and stored in zip-lock plastic bags until ready for further testing.

Flammability Testing

The test instruments used for evaluating the effects of the seven carriers on the flammability of the polyester and triacetate fabrics were the MKM Oxygen Index Flammability Tester and the 45^{o} Angle Flammability Tester. The Oxygen Index (OI) flammability test was chosen because it is a sensitive test which can often detect very small differences in the flammability of the fabric. In addition is is very reproducible and is applicable to a wide range of composite structures. The 45^{o} Angle Flammability Tester was chosen because it is perscribed in CS 191-53, Flammability of Clothing Textiles, which is the only federal standard that fabrics must pass before they can be used in apparel (11).

Oxygen Index Flammability Test

The Oxygen Index values of the untreated and carrier treated fabrics were tested in the MKM Oxygen Index Flammability Tester according to ASTM D 2863-76, Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics (Oxygen Index) (4). Oxygen Index (OI) is defined as the minimum concentration of oxygen in a mixture of oxygen and nitrogen that justs supports combustion under equilibrium conditions of candle-like burning. The equilibrium was established by the relation between the heat generated from the combustion of the specimen and the heat lost to the surrounding as was measured by the time of burning. This point was approached from both sides of the critical oxygen concentration in order to determine the oxygen index value for the fabrics evaluated in this study.

$$\text{Oxygen Index, } n\% = \frac{O_2}{O_2 + N_2} \times 100$$

Where O_2 = volumetric flow of oxygen, cm^3/s at the concentration determined; and

N_2 = corresponding volumetric flow rate of nitrogen, cm^3/s (4)

Ten samples, each measuring 12.7 X 5.0 cm, with the long dimension running parallel to the warp, were conditioned in a standard atmosphere for testing (i.e., $21 \pm 1^{\circ}$ C and $65 \pm 2\%$ RH). The instrument used for testing was a MKM Oxygen Index Flammability tester with standard metal sample frames. During testing, the oxygen concentration was adjusted until the sample would not burn for more than three minutes.

45^{o} Angle Flammability Test

The effects of carriers on the fabric's flammability was also tested by using the 45^{o} Angle Flammability Tester according to the procedure in CS 191-53, Flammability of Clothing Textiles (2). The standard provides a method for testing the flammability of clothing and textiles intended to be used for clothing. The test method establishes three classes of flammability: Class 1, Normal Flammability; Class 2, Intermediate Flammability; and Class 3, Rapid and Intense Burning. The test requires that a piece of fabric, when placed in the holder at a 45^{o} angle and exposed to flame for one second, does not ignite and spread flame up the length of the sample in less than 3.5 seconds for smooth fabrics and 4.0 seconds for napped fabrics.

Five samples, each measuring 5.08 X 15.25 cm, with the long direction running parallel to the warp, were positioned for 30 minutes at 105^{o} C $\pm$ 3^{o} C. The samples were then removed and placed over anhydrous calcium chloride in a dessicator for 15 minutes.

Individual specimens were positioned on the rack and adjusted so that the indicator finger just touched the fabric face. The stop-cord was strung, the chamber door closed, and the specimen ignited within 45 seconds of removing the specimen from the dessicator. For each specimen, the burning time and type of burning was recorded.

Statistical Analysis

The independent variables of fabric, carrier type, and carrier concentration were analyzed for significance using an analysis of variance procedure. The computer program used in the analysis was written in SAS. The Duncan's Multiple Range Test performed on the dependent variables to determine the effects of fabric type, carrier, carrier concentration, and interactions which were found to be significant in the analysis of variance procedure. The level of significance established for all tests was .05.

All of the statistical computer programs used in this study were obtained from the Kansas State University Statistics Laboratory.

Hypotheses

The specific hypotheses evaluated in this study were:

1. There will be no significant difference in the oxygen index values of the polyester and triacetate fabrics.
2. There will be no significant difference in the flame spread times of the polyester and triacetate fabrics.
3. There will be no significant difference in the oxygen index values of the polyester and triacetate fabrics treated with the seven carrier types.
4. There will be no significant difference in the flame spread times of the polyester and triacetate fabrics treated with the seven carrier types.
5. There will be no significant difference in the oxygen index values of the polyester and triacetate fabrics treated with the various concentration levels of carriers.
6. There will be no significant difference in the flame spread times of the polyester and triacetate fabrics treated with the various concentration levels of carriers.
7. There will be no significant interaction among carrier, concentration level, and fabric type on the oxygen index values of the polyester and triacetate fabrics.

8. There will be no significant interaction among carrier, concentation level, and fabric type on the flame spread times of the polyester and triacetate fabrics.

RESULTS AND DISCUSSION

The experimental fabrics used in this study consisted of polyester and triacetate fabrics laboratory treated with seven different carriers at four different concentration levels for a total of 28 treatments on each fabric type.

Two replicas of identically treated samples were prepared for testing. Each of the seven carriers was applied to samples at concentrations of 0.0, 1.0, 5.0, and 15.0% owf and tested for their effects on flammability by using the 45^{o} Angle Flammability Tester and the Oxygen Index Flammability Tester.

Evaluation of the 45^{o} Angle Flammability Test

The raw data and mean flame spread times for each replication of the polyester and triacetate fabrics at concentrations of 0.0, 1.0, 5.0, and 15.0% owf are presented in Tables A1 and A2 (see Appendix A). Each replication mean was based on five flame spread time measurements.

The overall means of the experimental fabrics, which were computed on the replica means, are presented in Tables 3 and 4. Throughout the tables and graphs, the following symbols were used to designate the carrier applied to the polyester and triacetate fabrics:

A: o-Phenyl phenol (Anthrapole 73)

B: Methyl salicylate (Anthrapole ND)

C: Biphenyl (Carolid AL)

D: Butyl benzoate (Chemcryl C-101-N)

E: Diphenyl oxide (Chemcryl JK-EB)

F: Methyl naphthalene (Dycar MN)

G: Perchloroethylene (Dilatin PT)

Table 3

Mean Flame Spread Times (45^{o} Angle Flammability Test) For Carrier-Treated Triacetate.

Carrier		Time (seconds)			
		Concentration (% owf)			
Code	Active Component	0.0	1.0	5.0	15.0
A	o-Phenyl phenol	12.96	13.84	11.38	11.86
B	Methyl salicylate	12.96	13.94	13.53	11.55
C	Biphenyl	12.96	13.85	12.52	11.67
D	Butyl benzoate	12.96	13.14	10.43	7.84
E	Diphenyl oxide	12.96	13.62	11.40	8.44
F	Methyl naphthalene	12.96	14.16	11.05	9.39
G	Perchlorotheylene	12.96	13.69	13.58	13.34

Table 4

Mean Flame Spread Times (45^{o} Angle Flammability Test) For Carrier-Treated Polyester.

Carrier		Time (seconds)*			
		Concentration (% owf)			
Code	Active Component	0.0	1.0	5.0	15.0
A	o-Phenyl phenol	---	---	---	----
B	Methyl salicylate	---	---	---	----
C	Biphenyl	---	---	---	----
D	Butyl benzoate	---	---	---	----
E	Diphenyl oxide	---	---	---	----
F	Methyl naphthalene	---	---	---	----
G	Perchloroethylene	---	---	---	----

* Not time recorded since sample failed to burn to the stop cord.

The 45° Angle Flammability Tester was used to determine if the treated fabrics would pass the standards set up by the Flammable Fabrics Act, or in other words, if the fabrics would pass the standard that industry must meet.

All the samples passed the 3.0 second flame spread time set-up by the standard. All of the polyester samples evaluated by the 45° Angle Flammability Tester were resistant to flame and flame spread times could not be recorded. Therefore, the polyester samples were not statistically analyzed.

The triacetate samples burned readily, but the flame spread times were slow enough to pass the federal flammability standard. The analysis of variance (ANOVA) statistical test (see Table 5) showed that carrier type and concentration had a significant effect on the flammability of the triacetate fabrics. In addition, the carrier x concentration interaction also was significant.

Table 5

Analysis of Variance for Flame Spread Times (45° Angle Flammability Test) on Triacetate.

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.1481	0.31	0.5831
Carrier	6	32.2381	11.20	0.0001*
Concentration	3	78.0615	54.22	0.0001*
Carrier x Concentration	18	37.2036	4.31	0.0003*
Total	28			

* 0.05 level of significance
Replication: 1,2
Carrier: o-phenyl phenol, methyl salicylate, biphenyl, butyl benzoate, diphenyl oxide, methyl naphthalene, and perchloroethylene
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

The results of the Duncan's Multiple Range Test for carrier type showed that, overall, triacetate fabrics treated with perchloroethylene, methyl salicylate, and biphenyl had the highest flame spread times (i.e., were the least flammable), whereas those treated with diphenyl oxide and butyl benzoate had the lowest flame spread times (i.e., were the most flammable (see Table 6 and Figure 2). Furthermore, the flame spread times of the triacetate fabrics progressively decreased, in general, as the carrier concentration increased, except for the fabrics treated with 1.0% owf carrier which showed an intital increase in flame spread time, thus indicating that these samples were less flammable (see Table 7 and Figure 3). This increase, however, was probably due to fabric shrinkage rather than to the carrier reducing the flammability. The amount of fabric shrinkage attributed to carrier dyeing can range from 8 to 18%.

Table 6

Duncan's Multiple Range Test for Mean Flame Spread Times (45° Angle Flammability Test) Associated with Carrier Types.

Carrier	Grouping*		Means (seconds)
Perchloroethylene		A	13.39
Methyl salicylate	B	A	13.00
Biphenyl	B	A	12.75
o-Phenyl phenol		C	12.51
Methyl naphthalene	D	C	11.89
Diphenyl oxide	D	E	11.61
Butyl benzoate		E	11.09

* Means with the same letter are not significantly different. 0.05 level of significance

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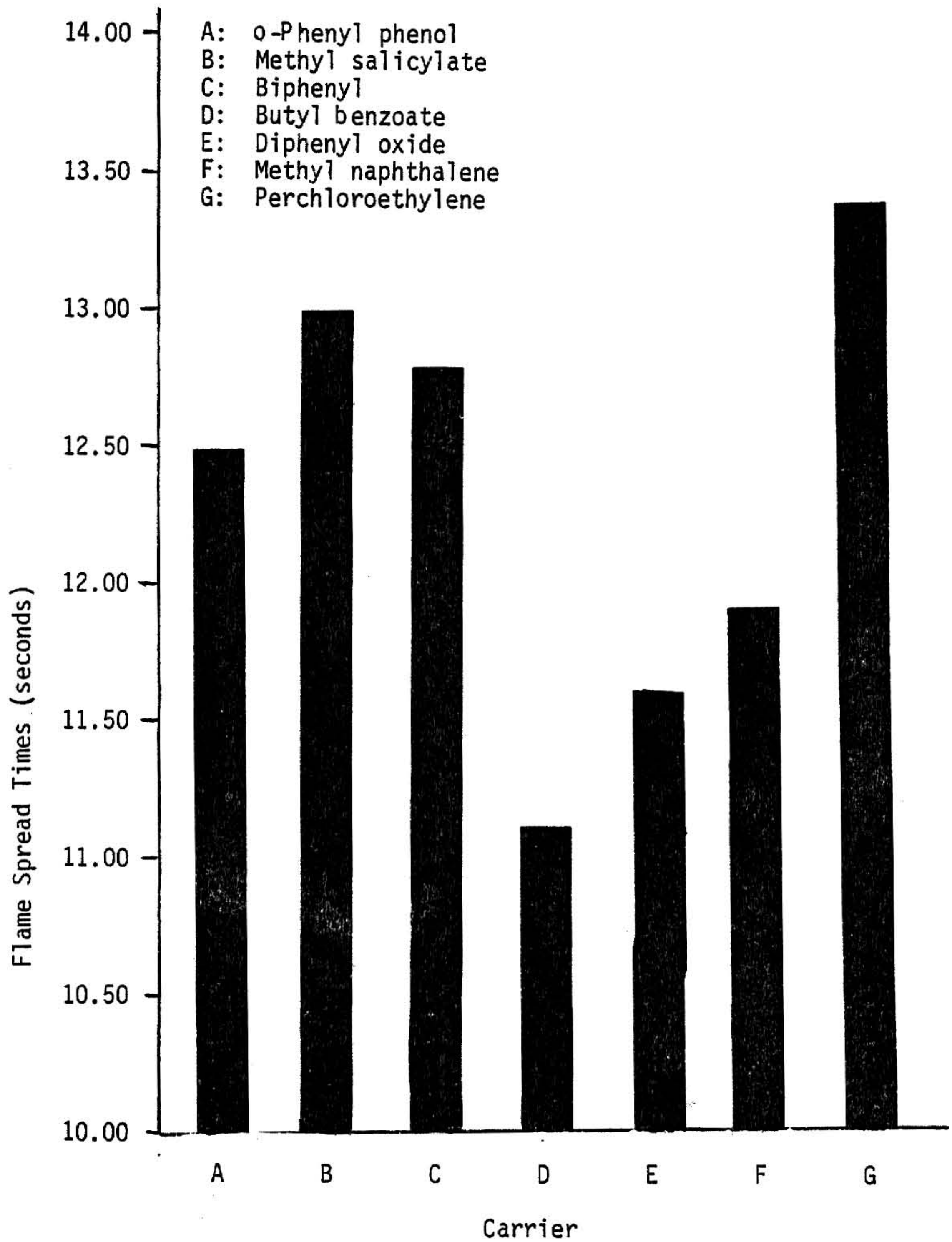

Figure 2: Mean Flame Spread Times (45^{o} Angle Flammability Test) for Carrier Types on Triacetate.

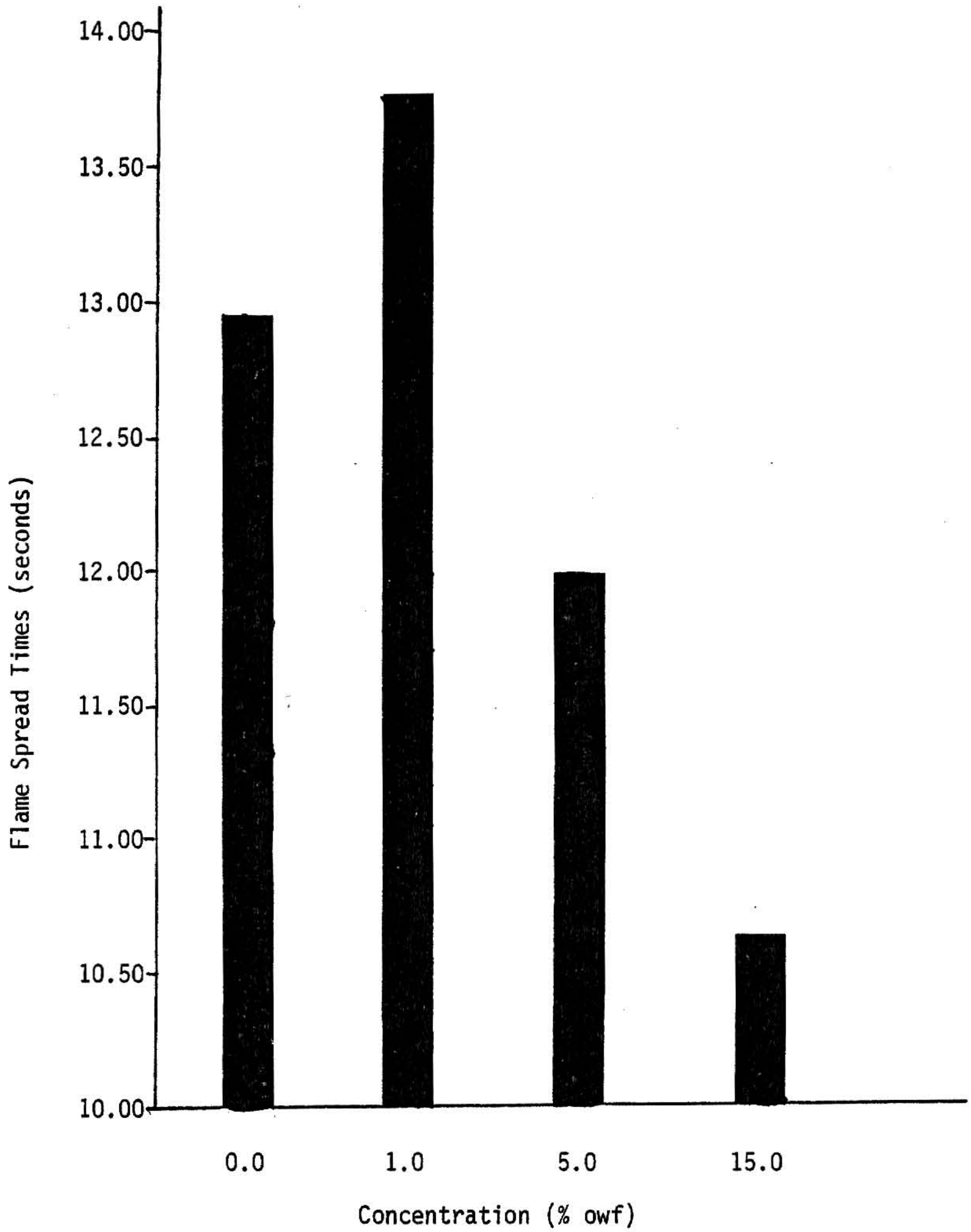

Figure 3: Mean Flame Spread Times (45^{0} Angle Flammability Test) For the Various Carrier Concentrations on Triacetate.

Table 7

Duncan's Multiple Range Test for Mean Flame Spread Times Associated with Carrier Concentration.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	13.75
0.0	B	12.96
5.0	C	11.98
15.0	D	10.58

* Means with the same letter are not significantly different. 0.05 level of significance

Since the carrier type x concentration interaction was significant, tests were performed on the flame spread time means for each of the seven carriers (see Appendix B: Tables B1-B14). Flame spread time means for the various concentation levels of the individual carriers are shown in Figure 4. In all cases, the 1.0% owf carrier application slightly decreased the flammability of the triacetate fabrics, that is, it increased the flame spread times. As mentioned previously, however, the decrease in the flammability as measured by the flame spread may be attributed to fabric shrinkage rather than to the carrier present in the fabric. The Duncan's Multiple Range Test performed on the flame spread time means for the various concentration levels of the individual carriers (see Tables B2, B4, B6, B8, B10, B12, and B14) showed that for o-phenyl phenol (Anthrapole 73), biphenyl (Carolid AL), and perchloroethylene (Dilatin PT) there was no significant difference between the untreated controls and the triacetate samples treated with these carriers at concentrations of 1.0, 5.0, and 15.0% owf. Thus, these

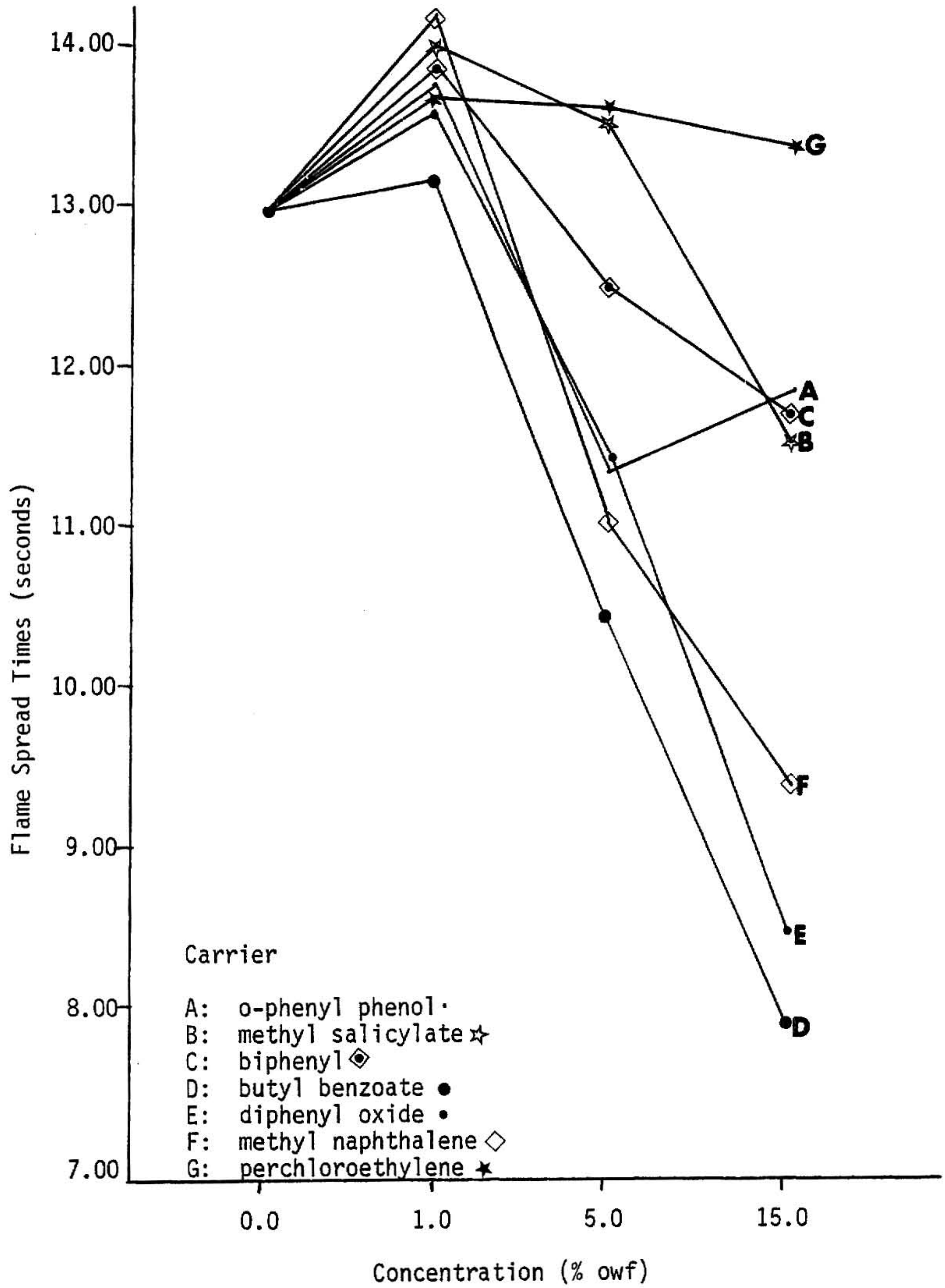

Figure 4: Mean Flame Spread Times (45^{o} Angle Flammability Test) for Each Concentration Level of Individual Carriers Applied to Triacetate.

carriers did not significantly increase the flammability of the triacetate fabrics. However, for triacetate fabrics treated with butyl benzoate (Chemcryl C-101-N), diphenyl oxide (Chemcryl JK-EB), and methyl naphthalene (Dycar MN), there was a significant increase in the flammability as shown by the decrease in flame spread times due to the concentration level. Flame spread times for concentrations of 0.0, and 1.0% owf were not significantly different but those for concentrations of 5.0 and 15.0% owf were significantly from the untreated controls and 1.0% owf concentrations from each other. Thus, these carriers did significantly decrease the flame spread times or increase the flammability of the triacetate fabrics.

To summarize, the 45^{o} Angle Flammability Test showed that there was a significant difference in the flammability of the triacetate fabrics treated with the seven carriers. An interaction was also associated with carrier x concentration. It was found that perchloroethylene, methyl salicylate, and biphenyl type carriers least effected the triacetate fabrics flammability, whereas diphenyl oxide and butyl benzoate most effected the fabrics flammability. In general, as the carrier concentration increased, the flammability increased, except at the 1.0% owf level.

Evaluation of the Oxygen Index Flammability Test

The raw data and mean oxygen index values for each replication of the polyester and triacetate carrier-treated samples at concentrations of 0.0, 1.0, 5.0, and 15.0% owf are presented in Tables A3 and A4. The mean for each replication was based on three Oxygen Index (OI) values.

The overall means, which were computed on the replica means, of

Table 8

Mean Oxygen Index Values for Carrier Treated Triacetate.

Carrier		Time (seconds)			
		Concentration (% owf)			
Code	Active Component	0.0	1.0	5.0	15.0
A	o-Phenyl phenol	18.40	18.43	18.18	18.25
B	Methyl salicylate	18.40	18.42	18.45	18.90
C	Biphenyl	18.40	18.32	18.45	18.59
D	Butyl benzoate	18.40	18.48	18.44	18.43
E	Diphenyl oxide	18.40	18.27	18.23	17.94
F	Methyl naphthalene	18.40	18.32	18.37	17.99
G	Perchloroethylene	18.40	18.37	18.23	18.62

Table 9

Mean Oxygen Index Values for Carrier Treated Polyester.

Carrier		Time (seconds)			
		Concentration (% owf)			
Code	Active Component	0.0	1.0	5.0	15.0
A	o-Phenyl phenol	31.83	32.30	32.33	31.49
B	Methyl salicylate	31.83	33.42	33.19	29.39
C	Biphenyl	31.83	32.05	31.09	26.77
D	Butyl benzoate	31.83	31.80	29.30	26.99
E	Diphenyl oxide	31.83	32.12	26.95	25.50
F	Methyl naphthalene	31.83	31.49	27.65	26.15
G	Perchloroethylene	31.83	32.44	29.95	27.52

the triacetate and polyester carrier-treated fabrics are presented in Tables 8 and 9, respectively. The analysis of variance statistical test showed that the independent variables which had a significant effect on flammability as measured by the Oxygen Index Flammability Test were carrier type, concentration, and fabric type. In addition the following interactions were significant: carrier x concentration, carrier x fabric, and carrier x concentration x fabric (see Table 10). The interactions of the various independent variables in this study may be seen by examining Figures 5 and 6. Because of these significant interactions (see Table 10), additional statistical tests were performed to more thoroughly analyze the effects of carrier types and concentrations on the flammability of polyester and triacetate.

The analysis of variance test applied to the OI values for triacetate (see Table 11) showed that there was a significant difference between carriers but that the differences were associated with specific concentration levels as evidenced by the significant carrier x concentration interaction. As shown in Figure 5, there is little variability in the data among the seven different carriers at the 1.0 and 5.0% owf levels. The significance lies in the 15.0% owf concentration. Figure 5 and Table 12 show that the triacetate samples treated with methyl salicylate exhibited the highest OI values overall and at a concentration of 15.0% owf. Furthermore, the flame resistant properties of the triacetate samples treated with methyl salicylate slightly increased as carrier concentration increased. Triacetate samples treated with diphenyl oxide and methyl naphthalene exhibited the lowest OI values overall and at a concentration of 15.0% owf. In general, the triacetate samples treated with these carriers exhibited a pro-

Table 10

Analysis of Variance for Oxygen Index Values on Polyester and Triacetate

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.1479	3.69	0.0601
Carrier	6	36.2933	150.75	0.0001*
Concentration	3	90.2426	749.65	0.0001*
Fabric	1	4083.8859	9999.99	0.0001*
Carrier x Concentration	18	28.8028	39.88	0.0001*
Carrier x Fabric	6	28.6533	119.01	0.0001*
Carrier x Conc. x Fabric	21	118.0825	140.13	0.0001*
Total	56			

* 0.05 level of significance

Replication: 1,2

Carrier: o-phenyl phenol, mehtyl salicylate, biphenyl, butyl benzoate, diphenyl oxide, methyl naphthalene, and perchloroethylene

Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Fabric: Triacetate and polyester

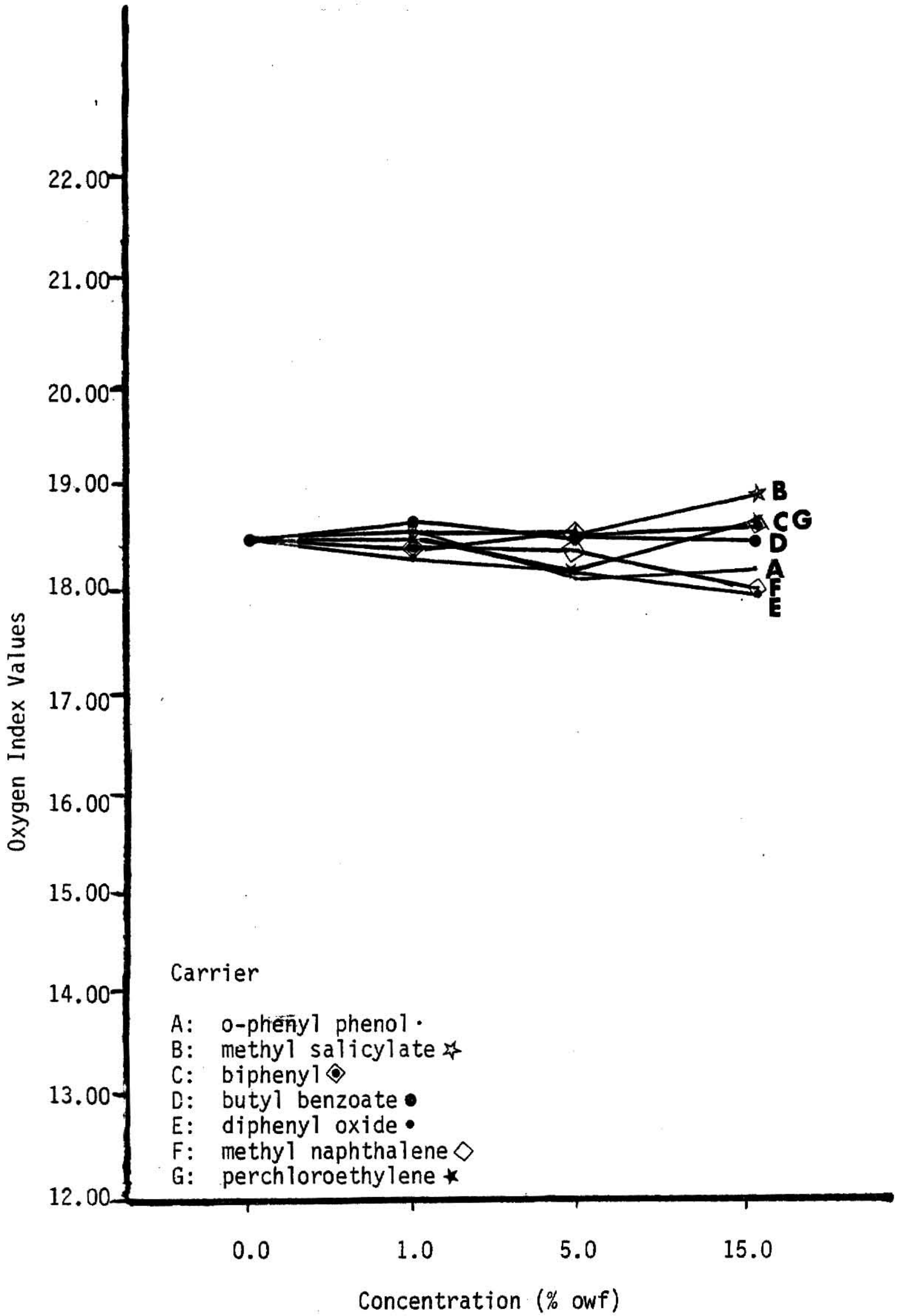

Figure 5: Oxygen Index Values for Each Concentration Level of the Individual Carriers Applied to Triacetate.

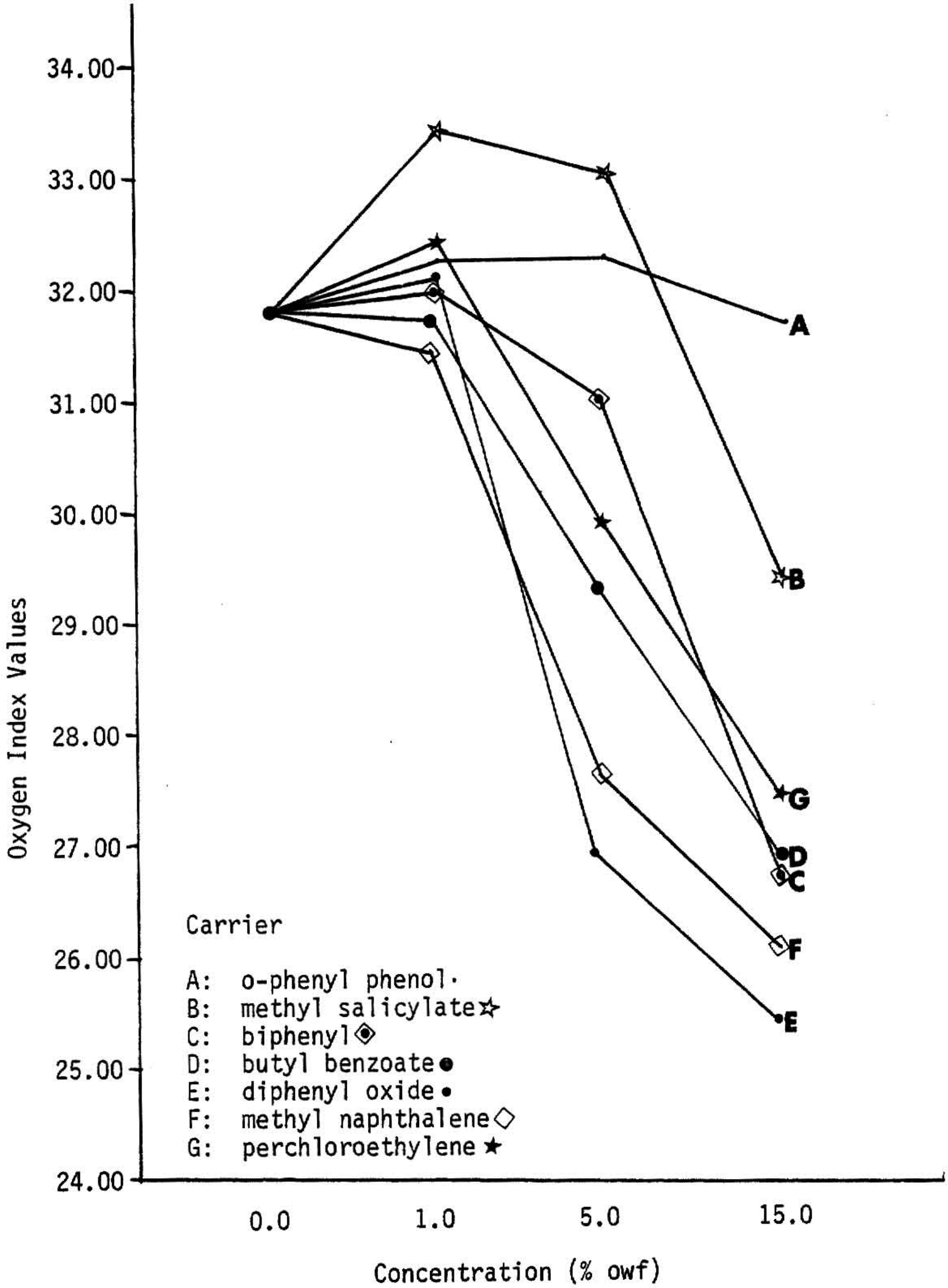

Figure 6: Oxygen Index Values for Each Concentration Level of the Individual Carriers Applied to Polyester.

Table 11

Analysis of Variance for Oxygen Index Values on Triacetate.

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0566	4.80	0.0373
Carrier	6	0.6405	9.06	0.0001*
Concentration	3	0.0250	0.71	0.5562
Carrier x Conc.	18	1.0574	4.98	0.0001*

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table 12

Duncan's Multiple Range Test for Oxygen Index Values Associated with Carrier Types on Triacetate.

Carrier	Grouping*	Means (OI Values)
Methyl salicylate	A	18.54
Biphenyl	B A	18.44
Butyl benzoate	B A	18.44
Perchloroethylene	B C	18.42
o-Phenyl phenol	D C	18.32
Methyl naphthalene	D	18.27
Diphenyl oxide	D	18.21

* Means with the same letter are not significantly different.
0.05 level of significance

gressive increase in flammability or a decrease in OI values as carrier concentration increased. O-phenyl phenol, biphenyl, butyl benzoate, and perchloroethylene, on the other hand, had very little effect on the OI values of the triacetate samples at all concentration levels.

The analysis of variance for polyester showed that carrier type and concentration had a significant effect on the fabrics OI values and that there was a significant interaction between carrier type and concentration (see Table 13). The Duncan's Multiple Range Test carried out on the carrier types (see Table 14) showed that o-phenyl phenol and methyl salicylate least affected the OI values of polyester, whereas methyl naphthalene and diphenyl oxide type carriers had the greatest affect on the OI values of the polyester fabrics. Figure 6 shows that at a 1.0% owf concentration, some of the carriers caused a decrease in fabric flammability (i.e., increased OI values). Once again this was probably due to fabric shrinkage. At a 5.0% owf concentration, the OI values for polyester were significantly decreased by all carriers except o-phenyl phenol and methyl salicylate, both of which exhibited higher OI values than the untreated controls (see Tables B29 through B42). All carriers except o-phenyl phenol significantly increased the flammability (i.e., decreased the OI values) of polyester at the 15.0% owf concentration.

To summarize, carrier type, concentration, and fabric type had a significant effect on flammability as measured by the Oxygen Index Flammability Test. There was also significant interactions between the independent variables. The triacetate samples treated with the seven different carriers did not show as great of a decrease in oxygen index values at the different concentration levels as did the poly-

Table 13

Analysis of Variance for Oxygen Index Values on Polyester.

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0936	1.34	0.2571
Carrier	6	64.3062	153.40	0.0001*
Concentration	3	180.1547	859.51	0.0001*
Carrier x Conc.	18	55.8909	44.44	0.0001*
Total	28			

* 0.05 level of significance
Replication: 1,2
Carrier: o-phenyl phenol, methyl salicylate, biphenyl, butyl benzoate, diphenyl oxide, methyl naphthalene, and perchloroethylene
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table 14

Duncan's Multiple Range Test for Oxygen Index Values Associated with Carrier Types on Polyester.

Carrier	Grouping*	Means (OI Values)
o-Phenyl Phenol	A	31.99
Methyl Salicylate	A	31.95
Perchloroethylene	B	30.43
Biphenyl	B	30.43
Butyl benzoate	C	29.98
Methyl naphthalene	D	29.28
Diphenyl oxide	D	29.10

* Means with the same letter are not significantly different.
0.05 level of significance

ester samples. Triacetate samples treated with methyl salicylate exhibited the highest OI values overall and at a concentration of 15.0% owf. Triacetate samples treated with diphenyl oxide, methyl naphthalene, and o-phenyl phenol exhibited the lowest OI values overall and at the 15.0% owf concentration.

The polyester samples were in agreement with the findings of the triacetate samples in that o-phenyl phenol and methyl salicylate had the highest OI values and that methyl naphthalene and diphenyl oxide had the lowest OI values, even though the differences ranged over a much wider area than with the triacetate samples. At the 5.0% owf concentration, polyester's flammability (i.e., as measured by the Oxygen Index Flammability Tester) was significantly increased by all carriers except o-phenyl phenol and methyl salicylate. All the carriers except o-phenyl phenol significantly decreased the OI values of polyester at the 15.0% owf Level.

Agreement Between Testers and Fabrics

Overall, it was found that the 45^{o} Angle Flammability Tester was more sensitive to detecting differences in flammability on the various carrier treated triacetate fabrics while the Oxygen Index Flammability Tester was better able to detect OI differences on the various carrier treated polyester fabrics. There was some general agreement between the two testers as to which carriers significantly alter the flammability of polyester and triacetate. Diphenyl oxide and methyl naphthalene type carriers most severely alter the flame spread times and OI values of the polyester and triacetate fabrics of the seven carrier types tested.

SUMMARY AND CONCLUSIONS

Two types of fabrics, regular polyester and triacetate were treated with seven different carriers, Anthrapole 73, Anthrapole ND, Carolid AL, Chemcryl C-101-N, Chemcryl JK-EB, Dycar MN, and Dilatin PT, each being representative of a different chemical class. The carriers were applied to the fabric at concentration levels of 0.0, 1.0, 5.0, and 15.0% owf. The treated fabrics were then tested for its flammability by using the 45^{0} Angle Flammability Tester and the Oxygen Index Flammability Tester. The data was then analyzed by an analysis of variance procedure and the independent variables tested for interactions by the use of a Duncan's Multiple Range Test.

The hypotheses tested in this study were rejected either partially or in full. That is, there was a difference in the oxygen index values and the flame spread times of polyester and triacetate. There was a significant difference in the oxygen index values of the polyester and triacetate fabrics treated with the seven carriers. It was found that methyl naphthalene and diphenyl oxide type carriers had the greatest effect on the fabrics oxygen index values and methyl salicylate and biphenyl had the least effect. In evaluating the carriers on the fabrics, it was found that the carrier had a greater effect on the polyester fabrics than the triacetate fabrics. With the triacetate fabrics, significance between carriers could not be detected until the 15.0% owf application and concentration did not prove to be a significant variable. On the polyester fabrics, significance could be determined at the 5.0 and 15.0% owf level and concentration did prove to be a significant variable.

There was no significant difference in the flame spread times of the polyester carrier treated fabrics. In general, the fabrics resisted flame and would not ignite, or if they ignited, thee flame extinguished quickly.

There was a significant difference in the flame spread times of the carrier treated triacetate fabrics. It was found that perchloroethylene, methyl salicylate, and biphenyl type carriers had the least effect on the triacetate falbrics flame spread times and diphenyl oxide and butyl benzoate had the greatest effect on the flame spread times.

Concentration was a significant variable on determining the flame times of the triacetate fabrics. In general, a 1.0% owf application slightly increased the flame spread times and a 5.0 and 15.0% owf application decreased the flame spread times of the triacetate fabrics with the 15.0% level most severely effecting it.

In both cases, there was a significant interaction among carrier x concentration x fabric type on the oxygen index values and the flame spread times of polyester and triacetate fabrics. To determine the type of interaction and its effects on the flame spread times and oxygen index values it was necessary to look at the carriers individually on the fabrics.

The results of this study showed that carrier removal is necessary so that flame spread times and oxygen index values are not decreased, resulting in an increase in flammability. Certain polyester and triacetate fabrics can still pass the federal standards for flammability of clothing even though residual carrier may be left on the fabric after dyeing and finishing. To the consumer, however, incomplete carrier removal may result in more flammable fabrics and garments being sold in the marketplace.

The two types of flammability tests performed in this study were only a few of the the many flammability tests currently available and they were concerned mainly with apparel applications. To thoroughly test the effects of carriers on the flammability of polyester and triacetate it would be necessary to use other fabric constructions and flammability testers.

RECOMMENDATIONS

This study has shown that carriers, the percent carrier, and the interaction of carrier and percent carrier applies significantly alters the flammability of regular polyester and triacetate fabrics. More research is needed in this area of study to determine if trace levels of carriers left on the fabric after washing will significantly alter the flammability of the fabric. Another area of interest would be to determine the percentage of the various carriers which would decrease the flammability of the fabric. A trend was shown in this study that a carrier application of 1.0% owf decreases the flammability of the fabric. More conclusive evidence is needed to see if this is a general trend for carriers or if the trend exhibited in this study was due to experimental error. A third area of study would be to determine if the chemical active ingredient in commercial carriers is effecting the fabrics flammability, or if it is due to the emulsification system of the carrier.

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Appendix A

Raw Data

Table A1

Flame Spread Times (45^{0} Angle Flammability Test) for Triacetate Samples

Carrier	Concentration (% owf)											
	1.0%				5.0%				15.0%			
	Replica 1 Time (seconds)	Type*	Replica 2 Time (seconds)	Type*	Replica 1 Time (seconds)	Type*	Replica 2 Time (seconds)	Type*	Replica 1 Time (seconds)	Type*	Replica 2 Time (seconds)	Type*
o-Phenyl phenol (Anthrapole 73)	12.1	BB	13.5	BB	----	--	10.5	BB	11.6	BB	10.9	BB
	13.8	BB	14.4	BB	12.5	BB	9.3	BB	11.4	BB	12.1	BB
	13.6	BB	14.6	BB	12.8	BB	10.1	BB	11.2	BB	13.0	BB
	14.4	BB	13.7	BB	12.8	BB	10.3	BB	10.9	BB	13.3	BB
	14.6	BB	13.7	BB	12.7	BB	10.1	BB	11.2	BB	13.0	BB
Avg.	13.7		14.0		12.7		10.1		11.3		12.5	
Methyl Salicylate (Anthrapole ND)	13.5	BB	13.6	BB	13.4	BB	12.5	BB	11.4	BB	10.5	BB
	14.3	BB	13.6	BB	13.7	BB	13.5	BB	11.4	BB	11.5	BB
	13.8	BB	14.3	BB	13.4	BB	14.6	BB	10.7	BB	11.2	BB
	14.4	BB	13.8	BB	13.1	BB	14.3	BB	12.7	BB	11.7	BB
	14.8	BB	13.3	BB	13.4	BB	13.4	BB	12.7	BB	11.7	BB
Avg.	14.2		13.7		13.4		13.7		11.8		11.3	
Biphenyl (Carolid AL)	13.8	BB	13.7	BB	13.4	BB	12.9	BB	11.1	SFBB	13.3	BB
	14.3	BB	14.3	BB	10.6	BB	14.2	BB	9.8	BB	12.7	BB
	14.1	BB	14.0	BB	12.7	BB	12.4	BB	10.1	BB	13.1	BB
	13.9	BB	13.8	BB	11.3	BB	12.9	BB	10.4	SFBB	13.0	BB
	12.4	BB	14.2	BB	11.6	BB	13.2	BB	9.9	SFBB	13.3	BB
Avg.	13.7		14.0		11.9		13.1		10.3		13.1	
Butyl Benzoate Chemcryl C-101-N	14.4	BB	12.6	BB	9.4	BB	11.9	BB	7.6	BB	6.7	BB
	14.1	BB	12.5	BB	10.0	BB	11.0	BB	7.8	BB	8.0	BB
	13.0	BB	12.7	BB	9.7	BB	11.1	BB	8.8	BB	6.0	BB
	13.2	BB	12.9	BB	10.2	BB	10.9	BB	7.9	BB	7.7	BB
	13.2	BB	13.0	BB	9.5	BB	10.6	BB	8.8	BB	9.1	BB
Avg.	13.5		12.7		9.8		11.1		8.2		7.5	

* BB: Base Burn
SFBB: Surface Flash Base Burn

Table A1 cont'd.

Carrier	1.0% Replica 1 Time (seconds)	1.0% Replica 1 Type	1.0% Replica 2 Time (seconds)	1.0% Replica 2 Type	5.0% Replica 1 Time (seconds)	5.0% Replica 1 Type	5.0% Replica 2 Time (seconds)	5.0% Replica 2 Type	15.0% Replica 1 Time (seconds)	15.0% Replica 1 Type	15.0% Replica 2 Time (seconds)	15.0% Replica 2 Type
Diphenyl Oxide Chemcryl JK-EB	13.3	BB	12.6	BB	12.8	BB	10.3	BB	8.1	BB	8.3	BB
	15.1	BB	13.9	BB	12.2	BB	11.1	BB	8.4	BB	9.8	BB
	13.8	BB	14.5	BB	11.4	BB	10.6	BB	7.3	BB	8.4	BB
	13.1	BB	12.7	BB	11.5	BB	11.4	BB	9.2	BB	8.6	BB
	13.4	BB	13.8	BB	12.4	BB	10.3	BB	9.2	BB	7.9	BB
Avg.	13.7		13.5		12.1		10.7		9.3		8.6	
Methyl Naphthalene (Dycar MN)	14.8	BB	13.8	BB	10.5	BB	11.6	BB	10.9	BB	8.2	BB
	13.6	BB	14.2	BB	11.5	BB	11.1	BB	9.3	BB	8.5	BB
	14.5	BB	14.3	BB	10.3	BB	11.1	BB	9.4	BB	9.1	BB
	15.5	BB	13.6	BB	11.0	BB	11.3	BB	9.4	BB	10.1	BB
	13.7	BB	13.6	BB	10.6	BB	11.5	BB	9.9	BB	9.1	BB
Avg.	14.4		13.9		10.8		11.3		9.8		9.0	
Perchloroethylene (Dilatin PT)	12.0	BB	13.8	BB	13.7	BB	13.5	BB	13.3	BB	13.3	BB
	13.6	BB	14.2	BB	14.2	BB	13.9	BB	13.5	BB	14.2	BB
	13.7	BB	14.6	BB	12.9	BB	13.1	BB	12.9	BB	13.7	BB
	13.9	BB	14.1	BB	13.7	BB	13.5	BB	13.7	BB	13.7	BB
	14.3	BB	12.7	BB	13.7	BB	13.6	BB	13.7	BB	12.9	BB
Avg.	13.5		13.9		13.6		13.6		13.4		13.3	

Carrier	0.0% Replica 1 Time (seconds)	0.0% Replica 1 Type	0.0% Replica 2 Time (seconds)	0.0% Replica 2 Type
Control (Untreated)	13.2	BB	12.1	BB
	13.8	BB	13.3	BB
	12.2	BB	13.2	BB
	13.2	BB	12.3	BB
	13.6	BB	12.7	BB
Avg.	13.2		12.7	

Table A2

Flame Spread Times (45^{o} Angle Flammability Test) for Polyester Samples

Carrier	Concentration (% owf)											
	1.0%				5.0%				15.0%			
	Replica 1 Time (seconds)	Type*	Replica 2 Time (seconds)	Type*	Replica 1 Time (seconds)	Type*	Replica 2 Time (seconds)	Type*	Replica 1 Time (seconds)	Type*	Replica 2 Time (seconds)	Type
o-Phenyl phenol (Anthrapole 73)	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	IBE	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE	----	DNI
Avg.	----		----		----		----		----		----	
Methyl Salicylate (Anthrapole ND)	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
Avg.	----		----		----		----		----		----	
Biphenyl (Carolid AL)	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
Avg.	----		----		----		----		----		----	
Butyl Benzoate (Chemcryl C-101)	----	DNI	----	DNI	----	DNI	----	IBE	----	IBE	----	IBE
	----	DNI	----	DNI	----	IBE	----	IBE	----	DNI	----	DNI
	----	DNI	----	DNI	----	IBE	----	IBE	----	DNI	----	DNI
	----	DNI	----	DNI	----	IBE	----	IBE	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
Avg.	----		----		----		----		----		----	

* BB: Base Burn
DNI: Did Not Ignite
IBE: Ignited But Extinguished

Table A2 cont'd.

Carrier	Concentration (% owf)											
	1.0%				5.0%				15.0%			
	Replica 1		Replica 2		Replica 1		Replica 2		Replica 1		Replica 2	
	Time (seconds)	Type	Time (seconds)	Type	Time (seconds)	Type	Time (seconds)	Type	Time (seconds)	Type	Time (seconds)	Type
Diphenyl Oxide (Chemcryl JK-EB)	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE
	----	IBE	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE
	----	DNI	----	DNI	----	IBE	----	DNI	----	DNI	----	IBE
	----	IBE	----	DNI	31.3	BB	----	DNI	----	IBE	----	IBE
Avg.	----		----		31.3		----		----		----	
Methyl Naphthalene (Dycar MN)	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE	----	DNI
	----	DNI	----	DNI	----	DNI	----	IBE	----	DNI	----	IBE
Avg.	----		----		----		----		----		----	
Perchloroethylene (Dilatin PT)	----	IBE	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI
	----	IBE	----	DNI	----	IBE	----	DNI	----	DNI	----	DNI
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE
	----	DNI	----	DNI	----	DNI	----	DNI	----	DNI	----	IBE
Avg.	----		----		----		----		----		----	

Carrier	0.0%			
	Replica 1		Replica 2	
	Time (seconds)	Type	Time (seconds)	Type
Control (Untreated)	----	DNI	----	DNI
	----	DNI	----	DNI
	----	DNI	----	DNI
	----	DNI	----	DNI
	----	DNI	----	DNI
Avg.	----		----	

Table A3

Oxygen Index Values for Triacetate Samples

Carrier	Concentration (% owf)					
	1.0%		5.0%		15.0%	
	Replica 1 OI Value	Replica 2 OI Value	Replica 1 OI Value	Replica 2 OI Value	Replica 1 OI Value	Replica 2 OI Value
o-Phenyl phenol (Anthrapole 73)	18.43	18.43	18.23	18.20	18.23	18.30
	18.43	18.43	18.23	18.10	18.13	18.40
	18.43	18.43	18.23	18.10	18.13	18.30
Avg.	18.43	18.43	18.23	18.13	18.16	18.33
Methyl salicyl-ate (Anthrapole ND)	18.53	18.33	18.53	18.40	18.63	19.20
	18.53	18.33	18.43	18.50	18.63	19.20
	18.53	18.23	18.43	18.40	18.63	19.10
Avg.	18.53	18.30	18.46	18.43	18.63	19.16
Biphenyl (Carolid AL)	18.33	18.40	18.43	18.40	18.53	18.60
	18.23	18.40	18.53	18.40	18.63	18.60
	18.23	18.30	18.43	18.50	18.53	18.60
Avg.	18.26	18.36	18.46	18.43	18.56	18.60
Butyl benzoate (Chemcryl C-101)	18.43	18.60	18.23	18.60	18.33	18.50
	18.43	18.50	18.33	18.60	18.33	18.60
	18.43	18.50	18.33	18.50	18.33	18.50
Avg.	18.43	18.53	18.30	18.56	18.33	18.53
Diphenyl oxide (Chemcryl JK-EB)	18.33	18.30	18.23	18.30	17.83	18.00
	18.23	18.20	18.23	18.20	17.93	18.00
	18.23	18.30	18.23	18.23	17.86	18.00
Avg.	18.26	18.26	18.23	18.23	17.86	18.00
Methyl naphtha-lene (Dycar MN)	18.33	18.30	18.13	18.40	17.93	18.10
	18.33	18.40	18.13	18.70	17.83	18.10
	18.23	18.30	18.23	18.60	17.83	18.10
Avg.	18.30	18.33	18.16	18.56	17.86	18.10

Table A3 cont'd.

Carrier	Concentration (% owf)					
	1.0%		5.0%		15.0%	
	Replica 1 OI Value	Replica 2 OI Value	Replica 1 OI Value	Replica 2 OI Value	Replica 1 OI Value	Replica 2 OI Value
Perchloroethylene (Dilatin PT)	18.33	18.40	18.23	18.30	18.63	18.50
	18.43	18.40	18.23	18.30	18.63	18.50
	18.33	18.30	18.33	18.30	18.63	18.80
Avg.	18.36	18.36	18.26	18.30	18.63	18.60

Carrier	0.0%	
	Replica 1 OI Value	Replica 2 OI Value
Control (Untreated)	18.43	18.40
	18.33	18.40
	18.43	18.40
Avg.	18.40	18.40

Table A4

Oxygen Index Values for Polyester Samples

Carrier	Concentration (% owf) 1.0% Replica 1 OI Value	1.0% Replica 2 OI Value	5.0% Replica 1 OI Value	5.0% Replica 2 OI Value	15.0% Replica 1 OI Value	15.0% Replica 2 OI Value
o-Phenyl phenol (Anthrapole 73)	32.03	32.70	32.23	32.40	31.43	31.50
	31.93	32.60	32.23	32.40	31.53	31.40
	32.03	32.60	32.23	32.50	31.53	31.50
Avg.	31.96	32.63	32.23	32.43	31.50	31.46
Methyl salicylate (Anthrapole ND)	33.43	33.40	33.33	33.30	29.83	28.90
	33.43	33.40	33.23	33.00	29.83	28.90
	33.43	33.40	33.23	33.10	29.93	28.80
Avg.	33.43	33.40	33.26	33.10	29.90	28.86
Biphenyl (Carolid AL)	31.83	32.20	31.03	31.00	26.73	26.80
	31.83	32.30	31.13	31.10	26.73	26.80
	31.83	32.30	31.13	31.10	26.73	26.80
Avg.	31.83	32.67	31.10	31.06	26.73	26.80
Butyl benzoate (Chemcryl C-101)	31.53	31.90	29.33	29.30	27.63	27.40
	31.73	31.90	29.33	29.30	27.53	27.40
	31.73	32.00	29.33	29.20	27.53	27.40
Avg.	31.66	31.93	29.33	29.26	27.56	27.40
Diphenyl oxide (Chemcryl JK-EB)	32.03	32.20	26.93	26.90	25.53	25.50
	31.93	32.30	27.03	26.90	25.53	25.50
	31.93	32.30	27.03	26.90	25.43	25.50
Avg.	31.96	32.26	27.00	26.90	25.50	25.50
Methyl naphthalene (Dycar MN)	31.43	31.50	27.63	27.70	26.33	25.90
	31.33	31.60	27.53	27.70	26.33	26.00
	31.43	31.60	27.60	27.70	26.33	25.90
Avg.	31.40	31.56	27.60	27.70	26.33	25.96

Table A4 cont'd.

Carrier	Concentration (% owf)					
	1.0%		5.0%		15.0%	
	Replica 1 OI Value	Replica 2 OI Value	Replica 1 OI Value	Replica 2 OI Value	Replica 1 OI Value	Replica 2 OI Value
Perchloroethylene (Dilatin PT)	31.83	32.90	29.83	30.00	27.53	27.50
	31.93	33.00	29.93	30.00	27.53	27.50
	31.93	33.00	29.93	30.00	27.63	27.40
Avg.	31.90	32.96	29.90	30.00	27.56	27.46

	0.0%	
	Replica 1 OI Value	Replica 2 OI Value
Control (Untreated)	31.83	31.90
	31.83	31.80
	31.83	31.80
Avg.	31.83	31.83

Appendix B

Statistical Analysis

Table B1

Analysis of Variance for Flame Spread Times (45° Angle Flammability Test) on Triacetate Treated with o-Phenyl Phenol (Anthrapole 73).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0098	0.01	0.9373
Concentration	3	7.3416	1.82	0.3168
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B2

Duncan's Multiple Range Test for Flame Spread Times (45° Angle Flammability Test) Associated with Concentration Levels of o-Phenyl Phenol (Anthrapole 73) on Triacetate.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	13.84
0.0	A	12.96
5.0	A	11.96
15.0	A	11.38

* Means with the same letter are not significantly different.
0.05 level of significance.

Table B3

Analysis of Variance for Flame Spread Times (45^{o} Angle Flammability Test) on Triacetate Treated with Methyl Salicylate (Anthrapole ND).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.1568	2.41	0.2180
Concentration	3	6.5370	33.56	0.0083*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B4

Duncan's Multiple Range Test for Flame Spread Times (45^{o} Angle Flammability Test) Associated with Concentration Levels of Methyl Salicylate (Anthrapole ND) on Triacetate.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	13.94
5.0	B A	13.53
0.0	B	12.96
15.0	C	11.55

* Means with the same letter are not significantly different.
0.05 level of significance

Table B5

Analysis of Variance for Flame Spread Times (45^{o} Angle Flammability Test) on Triacetate Treated with Biphenyl (Carolid AL).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	1.8432	1.84	0.2685
Concentration	3	4.9468	1.64	0.3469
Total	4			

0.05 level os significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B6

Duncan's Multiple RAnge Test for Flame Spread Times (45^{o} Angle Flammability Test) Associated with Concentration Levels of Biphenyl (Carolid AL) on Triacetate.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	13.85
0.0	A	12.96
5.0	A	12.52
15.0	A	11.67

* Means with the same letter are not significantly different.
0.05 level of significance

Table B7

Analysis of Variance for Flame Spread Times (45° Angle Flammability Test) on Triacetate Treated with Butyl Benzoate (Chemcryl C-101-N).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.04805	0.10	0.7780
Concentration	3	37.39495	24.66	0.0129
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B8

Duncan's Multiple Range Test for Flame Spread Times (45° Angle Flammability Test) Associated with Concentration Levels of Butyl Benzoate (Chemcryl C-101-N) on Triacetate.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	13.14
0.0	A	12.96
5.0	B	10.43
15.0	C	7.84

* Means with the same letter are not significantly different.
0.05 level of significance

Table B9

Analysis of Variance for Flame Spread Times (45^{o} Angle Flammability Test) on Triacetate Treated with Diphenyl Oxide (Chemcryl JK-EB).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.3698	1.59	0.2961
Concentration	3	31.9110	45.81	0.0053*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B10

Duncan's Multiple Range Test for Flame Spread Times (45^{o} Angle Flammability Test) Associated with Concentration Levels of Diphenyl Oxide (Chemcryl JK-EB) on Triacetate.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	13.62
0.0	A	12.96
5.0	B	11.40
15.0	C	8.44

* Means with the same letter are not significantly different.
0.05 level of significance

Table B11

Analysis of Variance for Flame Spread Times (45^{o} Angle Flammability Test) on Triacetate Treated with Methyl Naphthalene (Dycar MN).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0578	0.34	0.6002
Concentration	3	26.5068	52.16	0.0044*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf.

Table B12

Duncan's Multiple Range Test for Flame Spread Times (45^{o} Angle Flammability Test) Associated with Concentration Levels of Methyl Naphthalene (Dycar MN) on Triacetate.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	14.16
0.0	A	12.96
5.0	B	11.05
15.0	C	9.39

* Means with the same letter are not significantly different.
0.05 level of significance

Table B13

Analysis of Variance for Flame Spread Times (45^{o} Angle Flammability Test) on Triacetate Treated with Perchloroethylene (Dilatin PT).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.01805	0.29	0.6299
Concentration	3	0.62695	3.31	0.1759
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B14

Duncan's Multiple Range Test for Flame Spread Times (45^{o} Angle Flammability Test) Associated with Concentration Levels of Perchloroethylene (Dilatin PT) on Triacetate.

Concentration (% owf)	Grouping*	Means (seconds)
1.0	A	13.69
5.0	A	13.58
15.0	A	13.34
0.0	A	12.96

* Means with the same letter are not significantly different.
0.05 level of significance

Table B15

Duncan's Multiple Range Test for Oxygen Index Values Associated with Carrier Concentration Levels on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
0.0	A	18.40
15.0	A	18.39
1.0	A	18.37
5.0	A	18.34

* Means with the same letter are not significantly different.
0.05 level of significance

Table B16

Duncan's Multiple Range Test for Oxygen Index Values Associated with Carrier Concentration Levels on Polyester.

Concentration (% owf)	Grouping*	Means (OI Values)
1.0	A	32.23
0.0	B	31.83
5.0	C	30.06
15.0	D	27.68

* Means with the same letter are not significantly different.
0.05 level of significance

Table B17

Analysis of Variance for Oxygen Index Values on Triacetate Treated with o-Phenyl Phenol (Anthrapole 73).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.00045	0.08	0.7984
Concentration	3	0.08580	4.95	0.1110
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B18

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of o-Phenyl Phenol (Anthrapole 73) on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
1.0	A	18.43
0.0	B A	18.40
15.0	B A	18.25
5.0	B A	18.18

* Means with the same letter are not significantly different.
0.05 level of significance

Table B19

Analysis of Variance for Oxygen Index Values on Triacetate Treated with Methyl Salicylate (Anthrapole ND).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.00911	0.17	0.7104
Concentration	3	0.34584	2.11	0.2778
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B20

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Methyl Salicylate (Anthrapole ND) on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
15.0	A	18.90
5.0	A	18.45
1.0	A	18.42
0.0	A	18.40

* Means with the same letter are not significantly different.
0.05 level os significance

Table B21

Analysis of Variance for Oxygen Index Values on Triacetate Treated with Biphenyl (Carolid AL).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.00101	0.58	0.5017
Concentration	3	0.07424	14.17	0.0281
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B22

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Biphenyl (Carolid AL) on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
15.0	A	18.59
5.0	B	18.45
0.0	B	18.40
1.0	B	18.32

* Means with the same letter are not significantly different.
0.05 level of significance

Table B23

Analysis of Variance for Oxygen Index Values on Triacetate Treated with Butyl Benzoate (Chemcryl C-101-N).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0406	5.85	0.0943
Concentration	3	0.0065	0.31	0.8167
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B24

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Butyl Benzoate (Chemcryl C-101-N) on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
1.0	A	18.48
5.0	A	18.44
15.0	A	18.43
0.0	A	18.40

* Means with the same letter are not significantly different.
0.05 level of significance

Table B25

Analysis of Variance for Oxygen Index Values on Triacetate Treated with Diphenyl Oxide (Chemcryl JK-EB).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0021	1.00	0.3910
Concentration	3	0.2314	36.52	0.0073*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B26

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Diphenyl Oxide (Chemcryl JK-EB) on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
0.0	A	18.40
1.0	B A	18.27
5.0	B A	18.23
15.0	C	17.94

* Means with the same letter are not significantly different
0.05 level of significance

Table B27

Analysis of Variance for Oxygen Index Values on Triacetate Treated with Methyl Naphthalene (Dycar MN).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.05445	3.11	0.1758
Concentration	3	0.22025	4.20	0.1346
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B28

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Methyl Naphthalene (Dycar MN) on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
0.0	A	18.40
5.0	A	18.37
1.0	A	18.32
15.0	A	17.99

* Means with the same letter are not significantly different.
0.05 level of significance

Table B29

Analysis of Variance for Oxygen Index Values on Triacetate Treated with Perchloroethylene (Dilatin PT).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.00000	0.00	1.0000
Concentration	3	0.11825	131.39	0.0011*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B30

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Perchloroethylene (Dilatin PT) on Triacetate.

Concentration (% owf)	Grouping*	Means (OI Values)
15.0	A	18.62
0.0	B	18.40
1.0	B	18.37
5.0	C	18.29

* Means with the same letter are not significantly different.
0.05 level of significance

Table B31

Analysis of Variance for Oxygen Index Values on Polyester Treated with o-Phenyl Phenol (Anthrapole 73).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.08611	1.70	1.2835
Concentration	3	0.98454	6.47	0.0797
Total	4			

0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B32

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of o-Phenyl Phenol (Anthrapole 73) on Polyester.

Concentration (% owf)	Grouping*	Means (OI Values)
5.0	A	32.33
1.0	A	32.30
0.0	B A	31.83
15.0	B	31.49

* Means with the same letter are not significantly different.
0.05 level of significance

Table B33

Analysis of Variance for Oxygen Index Values on Polyester Treated with Methyl Salicylate (Anthrapole ND).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.18911	1.59	0.2961
Concentration	3	20.53004	57.63	0.0038*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B34

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Methyl Salicylate (Anthrapole ND) on Polyester.

Concentration (% owf)	Grouping*	Means (OI Values)
1.0	A	33.42
5.0	A	33.19
0.0	B	31.83
15.0	C	29.39

* Means with the same letter are not significantly different.
0.05 level of significance

Table B35

Analysis of Variance for Oxygen Index Values on Polyester Treated with Biphenyl (Carolid AL).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0288	1.22	0.3502
Concentration	3	36.8913	520.33	0.0001*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and15.0% owf

Table B36

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Biphenyl (Carolid AL) on Polyester.

Concentration (% owf)	Grouping*	Means (OI Values)
1.0	A	32.05
0.0	A	31.83
5.0	B	31.09
15.0	C	26.77

* Means with the same letter are not significantly different.
0.05 level of significance

Table B37

Analysis of Variance for Oxygen Index Values on Polyester Treated with Butyl Benzoate (Chemcryl C-101-N).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.1326	1.61	0.2943
Concentration	3	32.3347	130.68	0.0011*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B38

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Butyl Benzoate (Chemcryl C-101-N) on Polyester.

Concentration (% owf)	Grouping*	Means (OI Values)
0.0	A	31.83
1.0	A	31.80
5.0	B	29.30
15.0	C	26.99

* Means with the same letter are not significantly different.
0.05 level os significance

Table B39

Analysis of Variance for Oxygen Index Values on Polyester Treated with Diphenyl Oxide (Chemcryl JK-EB).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0050	0.33	0.6042
Concentration	3	68.3116	1518.04	0.0001*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B40

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Diphenyl Oxide (Chemcryl JK-EB) on Polyester.

Concentration (% owf)	Grouping*	Means (OI Values)
1.0	A	32.12
0.0	A	31.83
5.0	B	26.95
15.0	C	25.50

* Means with the same letter are not significantly different.
0.05 level of significance

Table B41

Analysis of Variance for Oxygen Index Values on Triacetate Treated with Methyl Naphthalene (Dycar MN).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.0010	0.04	0.8607
Concentration	3	47.6367	572.30	0.0001*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B42

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Methyl Naphthalene (Dycar MN) on Polyester.

Concentration (% owf)	Grouping*	Means (OI Values)
0.0	A	31.83
1.0	A	31.49
5.0	B	27.65
15.0	C	26.15

* Means with the same letter are not significantly different.
0.05 level of significance

Table B43

Analysis of Variance for Oxygen Index Values on Polyester Treated with Perchloroethylene (Dilatin PT).

Source of Variation	Degrees of Freedom	Sum of Squares	F	PR<F
Replication	1	0.1431	0.98	0.3958
Concentration	3	29.3569	66.82	0.0030*
Total	4			

* 0.05 level of significance
Replication: 1,2
Concentration: 0.0, 1.0, 5.0, and 15.0% owf

Table B44

Duncan's Multiple Range Test for Oxygen Index Values Associated with Concentration Levels of Perchloroethylene (Dilatin PT) on Polyester.

Concentration (% owf)	Grouping*	(OI Values)
1.0	A	32.44
0.0	A	31.83
5.0	B	29.95
15.0	C	27.52

* Means with the same letter are significantly different.
0.05 level of significance

THE EFFECT OF CARRIERS ON THE FLAMMABILITY OF POLYESTER AND TRIACETATE

by

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B. S., Kansas State University, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles, and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

ABSTRACT

Seven commercially prepared carriers of chemical types o-phenyl phenol, methyl salicylate, biphenyl, butyl benzoate, diphenyl oxide, methyl naphthalene and perchloroethylene were applied to polyester and triacetate fabrics at concentrations of 0.0, 1.0, 5.0, and 15.0% owf. The treated fabrics were tested for their flammability using the 45° Angle Flammability Tester and the Oxygen Index Flammability Tester.

All the fabrics tested in the 45° Angle Flammability Tester passed the 3.0 seconds flame spread time standard set-up in CS 191-53, Flammability of Clothing and Textiles. In general, for the treated polyester samples no flame spread times were recorded. Triacetate fabrics treated with perchloroethylene, methyl salicylate, and biphenyl were the least flammable, whereas those treated wtih diphenyl oxide and butyl benzoate were the most flammable. In general, as the carrier concentration increased, except for the fabrics treated with 1.0% owf carrier, the flammability progressively increased.

The Oxygen Index Flammability Tester showed that there was a significant difference between the fabrics, carriers and concentrations and their interactions. Triacetate samples treated with methyl salicylate exhibited the highest OI values overall and at concentrations of 5.0 and 15.0% owf. Triacetate treated with diphenyl oxide, methyl naphthalene, and o-phenyl phenol exhibited the lowest OI values overall and at the 15.0% owf concentration.

At the 5.0% owf concentration, polyester's flammability was significantly increased by all carriers except o-phenyl phenol and methyl salicylate. All the carriers except o-phenyl phenol significantly increased

the flammability of polyester at the 15.0% owf level.

Overall, there was good agreement between the two testers and it was found that butyl benzoate, diphenyl oxide, and methyl naphthalene type carriers most severely altered the flammability of polyester and triacetate of the seven carrier types tested.