DRINKA, MARY BETH. The Effect of Air Velocity on the Burning Characteristics of Selected Drapery Fabrics. (1975) Directed by: Dr. Pauline E. Keeney. Pp. 81.

The major purpose of this study was to investigate the burning characteristics of multiple layer fabric assemblies in varying air conditions. The burning characteristics of two layer fabric assemblies, with an air space between layers, was tested in conditions of moving and quiescent air. A fire resistance tester specially designed to incorporate moving air into the testing cabinet was used. The testing procedure followed was 34-1969 of the American Association of Textile Chemists and Colorists.

The experimental fabrics in the outer drapery layer were of cellulosic fiber content and included a 100% cotton, a 100% linen, a 100% rayon, and cotton and rayon blends. Each of the above groups included fabrics of medium and heavy weight. The second layer of the fabric assembly included a 100% cotton sateen and a 100% acetate thermal lining.

Data were collected by measuring seconds of afterflame time, seconds of afterglow time, and inches of fabric damage for each assembly. Data were analyzed based upon a factorial design. An analysis of variance was employed to determine the significance of each factor and interaction.

Because so few incidents of measurable fabric damage occurred and all other samples burned the entire length, afterflame and afterglow times were the burning characteristics that were analyzed statistically.

Air velocity was the single most important factor influencing burning characteristics. There was an indirect relationship between the effect of air velocity on afterflame and afterglow times. As air velocity increased, afterglow time decreased. Air velocity influenced the burning characteristics of the entire assembly significantly.

Fabric weight appeared to be a very strong factor in influencing burning characteristics. The two fabric weights produced a significant difference for both afterflame and afterglow. The heavy fabrics had higher afterflame and afterglow times than the medium weight fabrics.

The four fabric types in the outer layer influenced the burning characteristics of the entire assembly. Cotton and linen had similar afterflame times. Rayon had the shortest afterflame time. The cotton and rayon blend had the longest afterflame and afterglow times.

The most unexpected result of the study was related to the lining variable. The factor of lining within an assembly did not affect the flammability of the fabric assembly. The exception to this is the interaction of lining and air velocity for afterflame time. The cotton lining tended to produce a higher afterflame time and a lower afterglow time. The combination of moving air and lined drapery fabrics produced what often appeared to be hazardous and unpredictable burning conditions.

THE EFFECT OF AIR VELOCITY ON THE
BURNING CHARACTERISTICS OF
SELECTED DRAPERY FABRICS

by

Mary Beth Drinka

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Approved by

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APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

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TABLE OF CONTENTS

Chapter | Page

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The current interest in the hazards of flammable fabrics is being extended from apparel to interior furnishings items, including draperies and curtains. Both commercial and residential establishments have suffered deaths, injuries, and economic losses from accidental burning of drapery fabrics. Case histories of curtain and drapery fires reveal that over 55 percent of the fabrics ignited were of cellulosic content.[1]

Hanging as they frequently do in close proximity to windows, curtains and draperies frequently are exposed to air currents of varying velocities. This air might be in the form of drafts from the outside or from heating and air conditioning vents placed near the window. Because of this, the hazards of a fire could be increased. The amount of fabric hanging vertically could increase the fire hazard by forming a "chimney" effect between the drapery and lining fabrics.

Federal, state, and local governments are expanding their regulatory functions and stiffening their standards to seek protection from flammable drapery fabrics. Various factions including the United States military, the state of California, and the city of Boston have

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[1]Allan K. Vickers, "Drapery and Curtain Fires-Data Element Summary of Case Histories," U.S. National Bureau of Standards Publication No. COM-74-10128 (Washington D.C.: National Technical Information Service, July, 1973), p. 18.

taken the lead in legislative efforts to control death and destruction caused by flammable drapery fabrics. However, little research has been published on the burning characteristics of such items. The research which has been carried out reports the burning characteristics of fabrics varying in fiber content and fabric construction. This study was planned to concentrate on fabrics of cellulosic fiber content in both drapery and lining fabrics. The burning characteristics were determined by the vertical flame resistance testing apparatus specially designed by research personnel at the University of North Carolina at Greensboro and built for varying velocity of air.

Research personnel of the textile industry, members of the medical profession, government officials, and leaders of consumer groups are all interested in the problem of flammable fabrics. This study was planned to add to the information needed by such groups by simulating actual burning environments. It is only in such actual conditions that the hazards of fabrics and fabric combinations may be determined.

STATEMENT OF THE PROBLEM

The purpose of this study was to investigate the effect of air velocity on the burning characteristics of selected drapery fabrics.

The flammability test procedures to date do not tend to take into consideration layers of fabric. According to Krasney, few experiments with multiple layers are reported.[2] Nor has the effect of air

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[2]John F. Krasney, "Fabric Flammability: Needs for Research," Home Economics Research Journal, II, No. 3 (March, 1974), 165.

velocity been included in test procedures. Since many draperies are lined and are used in ambient atmospheres, it was of interest to study these factors.

The data collected will supplement Objective 2 of the experimentation of the Southern Regional Research Project S-86,[3] concerned with burning characteristics of two layers of fabrics, an outer drapery fabric and a lining fabric, in varying velocities of air. Results of experimentation showed that the burning characteristics were altered by changes in air velocity.

Objectives

The major purpose of this study was to investigate the burning characteristics of two layer assemblies in varying conditions of air circulation. The objectives of this study were as follows:

1. To determine the difference in the burning characteristics (afterflaming, afterglowing, and fabric damage) of selected drapery fabrics of medium and heavy weight.

2. To determine the burning characteristics of selected drapery fabrics when unlined and lined.

3. To determine the effect of air velocity upon the unlined and lined drapery fabrics.

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[3]Technical Committee, Southern Regional Research Center, "Manual of Procedures: Performance of Selected Fabrics Treated with Flame Retardant Finishes," (New Orleans: Cooperative State Research Service, 1971), p. 3. (Mimeographed).

Hypotheses

The following hypotheses were tested:

1. There is no significant difference in the burning characteristics (at the .01% significance level) of selected cellulosic drapery fabrics of heavy weight as compared to fabrics of medium weight.

2. There is no significant difference in the burning characteristics (at the .01% significance level) of selected drapery fabrics when unlined rather than lined.

3. There is no significant difference between unlined and lined fabrics (at the .01% significance level) when exposed to varying air velocities.

Assumptions

The following assumptions were made:

1. The difference in the burning characteristics due to the selected fiber contents, fabric weights, and fabric lining far outweighed the difference due to dissimilarities in fabric construction or coloration.

2. The fabrics chosen were representative of the cellulosics market in curtain and drapery fabric.

3. The quiescent air conditions in the cabinet were approximately the same as the standard conditions of the cabinet used in AATCC Test Method 34-1969.[4]

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[4]American Association of Textile Chemists and Colorists, Technical Manual, Vol. 49, (North Carolina: AATCC, 1973), 205.

Limitations

Preliminary research has been carried out on the burning characteristics of curtain and drapery fabrics of various fiber contents and constructions.[5] This study concentrated on cellulosics of medium and heavy weight fabrics, those that are likely to be lined. Because of the tremendous variety of curtain and drapery fabrics, no attempt was made to represent the entire market.

DEFINITION OF TERMS

The following terms have been included for clarification of the terms related to this study:

Afterflame Time. The time the fabric specimen continued to flame after the source of flame was removed expressed to the nearest 0.1 second.

Afterglow Time. The time of glow in the fabric specimen after the removal of the external source of fire exposure or after the cessation of flaming of the material expressed to the nearest 0.1 second.

Air Velocity. The speed of moving air measured in feet per minute and convertible to miles or kilometers per hour.

Fabric Damage. The extent to which the fabric is rendered unusable due to discoloration, fusion, or any other abnormal occurrence after the fabric has been tested as expressed to the nearest 0.01 inch.

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[5] J. M. Gregory & George H. Hotte, "Flammability of Fire Resistant Characteristics of Selected Drapery and Curtain Fabrics," Journal of Home Economics, LXIV, No. 3, (1972), 37-41.

Open Fabric Spacing. A dual layer fabric assembly in which the two fabrics were separated by an air space of one-eighth of an inch allowing air to circulate freely between layers.

CHAPTER II

SURVEY OF LITERATURE

Twentieth century America places tremendous emphasis on health and safety in the hope of human and environmental survival. A grave detriment to this ideal is that of flammable fabrics. A response to the awareness of the hazards that accompany burning fabrics is the ongoing trend to regulate the degree of fabric flammability. Federal governmental controls are expanding to children's sleepwear, mattresses, rugs and carpets, upholstery fabrics, automotive and airplane fabrics, and military fabrics. There is the possibility that the federal government should include drapery fabrics in its regulation of interior furnishings to protect the American people from death, injury, and economic loss in both commercial and residential establishments.

The major goal of this survey of literature was to review the need for federal controls for home furnishings and to summarize research pertinent to this study. It was therefore necessary to review sources dealing with the following topics: (1) introductory review of the importance of fire and fire related problems; (2) the importance of draperies and curtains as related to fire problems; (3) testing methods for the flammability of draperies and curtains; and (4) current status of flame retardant draperies and curtains. Since draperies and curtains are relatively new to the field of flammability, the small amount of existing drapery flammability research and current drapery fire statistics were highlighted. References related to the general area of fabric flammability were omitted. This literature survey compiled information on the specific topic of drapery and curtain flammability.

INTRODUCTORY REVIEW OF THE IMPORTANCE OF FIRES AND FIRE RELATED PROBLEMS

"Man's concern with hazards associated with ready combustibility of cellulosic materials, including textiles and wood, has been continuous since the discovery and utilization of fire," according to Dr. George L. Drake of the Southern Regional Research Laboratories.[1] That which is a source of warmth, fuel, and light can also injure, maim, or kill. This dual nature of fire exists from simple tribal cultures to our vast complex cities. Both have benefited and suffered because of fire. In our civilization citizens need to use the power of fire properly or suffer from its abuse.

An example of such abuse was the fire at the Vienna Ringtheatre on December 8, 1881. An estimated 450 people were killed. Theater fires occurred frequently in the nineteenth century when lamps set fire to curtains used on stage and to decorate the theater.[2] At this time

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[1]George L. Drake, Jr., "Fire Resistant Textiles," Kirk-Othmer Encyclopedia of Chemical Technology, ed. Herman F. Mark, 2nd ed. (NY: Interscience Publishers, 1966), IX, 300.

[2]E. W. Stark, "Liability Aspects of Textile Flammability," CIBA Review, No. 4 (1969), p. 23.

some of the drapery fabrics were so highly flammable that they did not simply ignite, but exploded. In contrast, a modern-day asbestos safety curtain was credited with confining a blaze in Ontario, Canada. The lives of over 1000 people were endangered when an overheated spotlight ignited stage draperies. The damage was limited to the stage and floor because of the safety curtain.[3] Unfortunately, this is rarely the case. We are much more likely to remember reading in newspapers about disasters like the Cocoanut Grove night club fire in Boston on November 28, 1942. A discarded cigarette probably ignited decorator fabrics causing 432 people to lose their lives.[4] A catastrophe such as this was necessary to prompt the introduction of the United States flammability legislation.

Great conflagrations like the most destructive of hurricanes are given names in the annals of history. The Great Chicago Fire of 1871, the Baltimore Fire of 1904, the San Francisco Fire of 1906, and the Augusta Fire of 1936 are among the most remembered for they took the greatest tolls.[5] It is impossible to estimate what role draperies had in acting as a fuel source of these fires when they could have been a barrier to flame spread.

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[3] "Asbestos-Safety Curtain," Asbestos Producer, (January 1973), p. 104.

[4] Stark, op. cit., p. 7.

[5] J. W. Kerr, "Historic Fire Disasters," Fire Research Abstracts and Review, by the National Academy of Sciences, XIII, No. 1, (1971), 2-14.

Fire Statistics

The fire problem in the United States gave sufficient cause for the formation of the National Commission on Fire Prevention and Control. The Commission consists of a cross-section of experts and representative organizations in the United States in the area of public health and safety. This group of nationally known individuals includes scientists, hospital administrators, government officials, professors, and authorities in fire service. In 1973 the Commission completed their two year study giving the status of the problem and recommendations for the future. Burning America is the title of their report. It is compulsory reading if one is to understand the fire problem in this country.

According to the data the Commission collected, fire claims 12,000 Americans annually in addition to the tens of thousands who are physically and emotionally scarred by fire. Among the causes of accidental deaths fire victims fall third with only motor vehicle accidents and falls ranking higher. The cost of destruction has been conservatively estimated at $11.4 billion or 1 percent of the Gross National Product. This ranks fire losses of the United States as the highest in the world. The United States reports a deaths-per-million rate of 57.1 which is nearly twice that of second ranking Canada, in spite of the fact that it is the richest, most technologically advanced nation.[6]

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[6]National Commission on Fire Prevention and Control, America Burning, by Richard E. Bland, (Washington, D.C.: Government Printing Office, 1973) p. 1.

Fire Dynamics

Extensive research was conducted on fabric flammability and especially on the pyrolysis of cotton. Investigations should also be carried out concerning the other aspect of the problem, the fire itself. J. W. Kerr, director of Support Systems Research of the Office of Civil Defense stated that "every fire is a gamble with the unknown."[7] The unpredictability of a fire complicates the hazard. "Almost nobody has understanding of the strategy needed to cope with a huge conflagration."[8]

A thorough analysis of fire behavior was triggered in Tokyo in 1923. There was a horrendous fire associated with an earthquake. Lives lost totalled 91,344. Many of these victims had taken refuge in open areas. Deaths were due to fire whirlwinds of tornado intensity which swooped across huddled refugees.[9]

Wind is an active factor in the largest fires. "It is the wind that allows fires to leapfrog the defensive lines, the firebreaks, thus starting a whole new series of ignitions farther along."[10] Air movement, winds, and fire spread mechanisms make fire control seemingly impossible at times for the burning becomes highly turbulent. There is a lack of information on the effects of drafts from air conditioning and heating units on burning draperies. Fire performance depends on such factors as physical layout, the interaction between walls and ceilings,

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[7]The Commission on Fire Prevention and Control, ibid., p. 2.

[8]Kerr, op.cit., p. 3. [9]Kerr, ibid., p. 1. [10]Kerr, ibid., p. 3.

fuel loads (draperies), and the presence of complicating components such as air conditioning ducts. This area needs further study.[11]

The dominant areas of uncertainty are the fire mechanisms for fire spread. These mechanisms are convection, radiation, and firebrand.[12]

Convection. The heat released in a fire expands the gas next to it and the gas rises. This buoyancy of gases draws fresh air into the fire. The oxygen is the fuel that sustains and spreads the fire. Convection is the principle by which smoke goes up a chimney or causes a building to turn into an inferno in a matter of minutes. It can cause fire to spread between floors of high rise buildings.[13] It is this vertical spread that is most likely to occur in drapery fires.

Radiation. This mechanism causes fire to spread from one building to another across an alley or narrow street, or from house to house. It is a deceptive method of flame spread between houses or within a room; sections are set fire that are out of reach of the flame. Radiation is a horizontal movement that is much more likely to occur if windows of a house are left open. Windows are the path of entry, rather than roofs or porches.[14]

Firebrand. Firebrand is the long distance fire spread mechanism. Firebrands can be carried miles by high winds.[15]

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[11]The Commission of Fire Prevention and Control, op. cit., p. 12.

[12]Kerr, op. cit., p. 2. [13]Kerr, ibid., p. 8. [14]Kerr, ibid.

[15]Kerr, ibid.

Another critical phenomenon is flashover time. This is the time it takes a fire to spread rapidly throughout a room. Until then a person would be able to crawl to safety. At flashover time the value of essentially everything in a room is destroyed. Actual fire tests conducted in bedrooms show approximately 8 minute flashover time. Any delay in flashover time would give an occupant that much more time to escape and firemen more time to respond. (An example of such delay was due to a synthetic drapery melting and falling to the floor. The flashover time almost doubled.) Retardants in draperies might also delay flashover. Such a simple change as replacing flammable curtains with flame retardant ones can cause such a significant delay.[16]

Causes of the United States' Fire Problem

According to the Commission on Fire Prevention and Control, "Efforts of individuals and fire protection organizations have run against the twin tides of ignorance and indifference-tides which contribute substantially to the extraordinary magnitude of the fire problem in the U.S."[17] This suggests that most of us regard fire as a remote danger causing indifference. The federal government as well as the citizens of the United States have also been largely indifferent to the problem. The fire problem has barely begun to reach the American conscience.[18] Flammability legislation was not enacted until the past two

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[16]Howard W. Emmons, "Fire & Fire Protection," Scientific American, CCXXXI, No. 1 (July, 1974), 25.

[17]The Commission on Fire Prevention and Control, op.cit., p. 2.

[18]The Commission on Fire Prevention and Control, ibid., p. 24.

decades of this century. Preventative measures, the crux of legislation, are only effective if brought down to the family or individual level for most fires are, in fact, due to carelessness.

It is only recently that our eyes are being opened to the fact of how dangerously flammable fabrics can be. "Everyone knows gasoline is dangerous, but not everyone knows about highly flammable textiles. That is the crucial difference."[19] It is a matter of public awareness. No longer can we regard fabrics for clothing and shelter as protective when they can be so hazardous.

Besides the problem of ignorance and indifference is that of culture lag. Increased urbanization, along with its clogged city streets, bigger and higher buildings, ghettos, and dilapidated buildings are kindling for fire. According to the Committee on Fire Research of the National Research Council, "growth in the knowledge of how to cope with fire has not kept pace with the growth of the fire problem."[20]

The fire problem is growing due to the technological revolution. New materials and products are in use with little regard for toxic or aggravating effects in case of fire. Many homes contain an array of appliances and conveniences that are potential fire sources for draperies and other decorative fabrics. There is no corresponding revolution in the fire services or in burn treatment in hospitals.[21]

Actual causes of fire include the following: building defects

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[19]Stark, op. cit., p. 24.

[20]The Commission on Fire Prevention and Control, op. cit., p. 2.

[21]The Commission on Fire Prevention and Control, ibid., p. 7.

cause approximately 20 percent of deaths due to fire; products or processes make up another 9 percent; and the remaining 71 percent are due to man's actions.[22]

Environmental Hazards

"In this built environment, as it is called, Americans live side by side, day and night, with ignitable materials, combustible furniture and upholstery, and products and appliances which may offer dangerous fire potential."[23] In 1971, 7 out of 10 fires occurred in residential occupancies. This accounts for one-half of the fire deaths and one-third of property losses. Eighty percent of multiple-death fires occur between 11 P.M. and 6 A.M. when most people sleep. Fire occurs at all socio-economic levels.[24]

The Commission believes that Americans are fooled by a false sense of security that the modern urban environment imparts. The newness and simplicity of so many buildings conveys the feeling that they are invulnerable to destruction by fire. A building's contents as well as structure must be considered.

Under no circumstances do synthetic fabrics stand alone as fire hazards. Natural materials can release toxic gases and many, like cellulosics, ignite at a lower temperature than synthetics. Conditions

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[22]The Commission on Fire Prevention and Control, ibid., p. 57.

[23]The Commission on Fire Prevention and Control, ibid., p. 53.

[24]The Commission on Fire Prevention and Control, ibid., p. 54.

of the air, rather than flames, are generally the cause of deaths due to fire. Lack of oxygen, superheated air, smoke, and toxic products, in that order, all come before flame as to the ways in which fire can kill.[25] Burning fabrics produce all of the above effects.

The American Society of Testing Materials and the National Fire Protection Agency have set up standards for measuring fire resistance of materials. Several issues must be resolved in hope of better protection. A standardized test method needs to be devised to measure the rate and amount of smoke products. Tests must simulate the complexities of real fires. Economic interests of product manufacturers must be directed so as to avoid running counter to more stringent fire safety requirements. Building codes should be extended to cover interior furnishings; and fire prevention codes need to apply to private as well as commercial and industrial dwellings. Compulsory labeling requirements are necessary enabling consumers to evaluate hazards of products they bring into their homes.[26]

Federal initiative is needed to close gaps between voluntary efforts of the industry and loopholes in standards and building codes. In 1972, Congress created the Consumer Product Safety Commission authorizing it to "conduct research, studies, and investigations on the safety of consumer products and on improving the safety of such products."[27] It can set standards of design and composition, can require labeling of

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[25]The Commission on Fire Prevention and Control, ibid., p. 63.

[26]The Commission on Fire Prevention and Control, ibid., p. 64.

[27]The Commission on Fire Prevention and Control, ibid., p. 67.

hazards or instructions for safe use, and can ban products that present unreasonable risk of injury.[28]

Flammable fabrics do sometimes present unreasonable risks. Annually 3,000 Americans die after clothing catches fire and over 150,000 are injured. The National Commission on Fire Prevention and Control believes fabric flammability will be a high priority issue of the Consumer Products Safety Commission. Specifically the Commission pointed out the following needs to the Consumer Products Safety Commission, for it is obvious that fire safety lags behind economic and aesthetic considerations in product manufacture: (1) research to improve flame retardant processes; (2) extension of standards into further categories of fabric use; (3) development of labeling requirements for other categories; (4) educational efforts for public awareness.[29]

An especially urgent need is for fire safety of the occupants of nursing homes and homes for the elderly. Annually 3,500 - 4,000 fires occur in these facilities.[30] The amount of combustibles in these institutions including furnishings is a high priority issue. Both bedding and draperies should meet high standards.

THE IMPORTANCE OF DRAPERIES AND CURTAINS AS RELATED TO THE FIRE PROBLEM

Drapery and Curtain Market

Over a century ago Scientific American (July, 1861) advocated

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[28]The Commission on Fire Prevention and Control, ibid.

[29]The Commission on Fire Prevention and Control, ibid., p. 68.

[30]The Commission on Fire Prevention and Control, ibid., p. 127.

the use of non-flammable materials for ladies dresses.[31] Not until recently has action been taken to reduce the number of fire accidents. There is indication that this awareness is also reaching the consumers of draperies and curtains. When women were asked in an Owens-Corning survey on what basis they bought draperies and curtains, they listed fire resistance as one of the characteristics of preference.[32] Yardage for the market is expected to grow significantly between 1975-1980 from 1.2 billion yards to 1.8 billion yards.[33] The question is how much of this yardage will be flame retardant.

At the present time the market appears to have only a very small percentage of flame retardant treated fabrics or fabrics made of inherently flame retardant fiber. Two basic ways of improving the flame retardancy of drapery and curtain fabrics are being pursued. The first method consists of adding a flame retardant finish to the fabric. The second method consists of constructing the yarns of inherently flame retardant fiber. Presently, both methods are in use and will be discussed. A summary of the literature indicates that the trend is going toward flame retardant finishes on cellulosics and toward inherently flame retardant synthetic fibers which are now being developed. Perhaps the industry will view the changeover from flammable to non-flammable

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[31]E. B. Nielsen & H. R. Richards, "Fabric Flammability: A Proposed Method for Measuring the Rate-Of-Burn," Textile Chemist & Colorist, I, No. 12 (June 4, 1967), 27.

[32]Herbert Koshetz, "Curtain Market's Bright Outlook," New York Times, September 22, 1974, p. 12.

[33]Koshetz, ibid.

draperies as a new marketing venture rather than as an added expense as was done with flame retardant sleepwear.

Drapery and Curtain Fire Statistics

In very recent years there has been a sharp increase in the number of organizations collecting data on burn statistics. The kind and volume of information is also increasing. An information network exists between hospitals, fire services, the fire incident itself, and the computer with the backing of public safety organizations. These groups include the Information Council on Fabric Flammability and the National Bureau of Standard's Flammable Fabric Accident Case and Testing System (FFACTS). Data from such organizations is providing a large scale picture so that fire may be dealt with more effectively.

According to B. Buchbinder, the Acting Chief of the Office of Information and Hazard Analysis of the National Bureau of Standards, it was found that home furnishings fabrics were the first to ignite in 285,000 cases followed by clothing in 159,000 cases. The home furnishings fabric primarily includes carpets and rugs followed by draperies.[34]

McDonald found that the textile products were most frequently the primary agent ignited (33 percent) with flammable liquid second (25 percent). Household textiles accounted for 71 percent of textile products ignited and apparel items accounted for the remaining 29 percent.[35]

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[34] B. Buchbinder, "Preliminary Indications from Survey of U.S. Household Fire Experience," Sources & Resources, 1975/1, pp. 4-5.

[35] K. McDonald, "Accidental Burn Injuries: A Review," Textile Chemist & Colorist, III, No. 4 (April, 1971), 35.

The Fire Technology Division of the National Bureau of Standards is involved in a continuing investigation into deaths, injuries, and economic losses resulting from accidental burning of textile products. A preliminary examination of 1,567 computerized case histories from the Flammable Fabric Accident Case and Testing System indicated 77 incidents in which draperies and curtains were involved in fires. The data bank may establish the need of a federal standard. As a result of burning draperies,15 died and 47 were injured. The draperies were the first to ignite in 28 of 55 incidents in which the source was known. Property losses were estimated at $135,835.[36]

More specifically, the following data were collected. In reference to location, 90 percent of the cases occurred in private residences; these accidents occurred in 20 states; and the fires themselves were equally distributed among the kitchen, living room, and bedroom. The incidents took place during normal activity in the kitchen and throughout the day in the bedroom and living room. As to characteristics of the victims, the ages of 27-45 and over 66 were most highly represented. They were not under the influence of intoxicants nor physically handicapped. The annual income was under $8,000 in 60 percent of the cases. Three-fourths of the homes were valued at less than $20,000. Over one-half of those involved lived in rented units and paid under $101 per month.

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[36]Allan K. Vickers, "Drapery and Curtain Fires-Data Element Summary of Case Histories," U.S. National Bureau of Standards Publication No. COM-74-10128 (Washington D.C.: National Technical Information Service, July, 1973), pp. 1-2.

In reference to ignition, it was primarily due to kitchen ranges, matches, or cigarettes with 18.6 percent of the cases occurring during sleeping, 18.6 percent while smoking, 13.9 percent while cooking, and 11.9 percent occurring when playing with matches or lighters. Cause of death in 10 of 15 deaths was due to smoke inhalation. In 11 fatalities draperies and curtains contributed to flame spread but were not the first fabrics ignited.[37]

Cotton was the most common fiber (25.5 percent) followed by acetate/rayon blend (14.5 percent), glass fiber (12.7 percent), cotton/rayon blend (10.9 percent) and all rayon (5.5 percent). Most fabric weights involved were between 4.1 - 6.0 oz./yd.^{2} (28.6 percent) and 6.1 - 8.0 oz./yd.^{2} (28.6 percent).[38]

Drapery Flammability Legislation and Standards

Flammability legislation has been characterized by the occurrence of significantly newsworthy fire disasters to trigger the conscience of lawmakers and the awareness of the general public.

Federal legislation regulates only the most highly flammable drapery and curtain fabrics. The Amendment to the Fabric Flammability Act of 1967 gave the Secretary of Commerce authority to develop test methods and issue flammability standards. All wearing apparel and interior furnishings fabrics, including imports and interstate merchandise,

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[37]Vickers, ibid., pp. 4-7, 16.

[38]Vickers, ibid., pp. 7, 19.

were included to protect the life, health, and property from extremely hazardous flammable fabrics.[39]

State and local legislation, now in its early stages, will be reviewed. Federal and commercial standards will be presented. The status of an across-the-board federal standard will be discussed.

State and Local Legislation Affecting Draperies and Curtains

State of California. California has historically been a pacesetter in the field of fabric flammability enacting legislation prior to the U.S. government and all other states. Other legislation is very similar to the legislation of the state of California. Only differences will be pointed out. Many states have and will continue to pattern their legislation after California's Title 19 - Public Safety Code. A part of the test relating to draperies is stated in full.

> It is unlawful for any person, firm, or corporation to establish, maintain, or operate any night club, restaurant, cafe, or any similar place where alcoholic liquors are sold for consumption on the premises, or any dance hall, skating rink, theatre, motion picture theatre, auditorium, school, or any other place of amusement, entertainment, instruction, display, or exhibition, unless all drapes, hangings, curtains, drops, and all other similar decorative materials that would tend to increase the fire or panic hazard, are made from a non-flammable material or are treated and maintained in a flame-retardant condition.[40]

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[39]U.S. Congress, "Amendment to the Flammable Fabric Act," Public Law 90-189, 81 stat. 568, December 14, 1967. p. 569.

[40]California State Fire Marshall, Excerpts from Laws & Regulations Relating to "Flame-Retardant Chemicals, Fabrics, & Application Concerns, California Administrative Code Title 19 - Public Safety," by Albert E. Hole, (August 19, 1972), p. 165.

California has a similar code for carnivals, circuses, tent shows, and side shows. Interlinings must be treated on the lower accessible portion.[41] The vertical flame test, AATCC Test Method 34-1969 with minor variations is used as a basis for judging the degree of drapery flammability in most organizations. However, acceptance criterion is not uniform between any factions whether governmental, commercial, or military.

New York City. The New York City regulations cover textiles, draperies, decorative items, office furniture and furnishings in places of public assembly. Certification is of two types. This is determined by the fiber, whether it was inherently safe or was rendered safe by chemical after-treatment. The manufacturer is to submit a written copy of certification. Processing such as ironing, sewing, and normal handling is to have no detrimental effects on treated drapery fabric.[42]

Port Authority of New York & New Jersey. This area has patterned its drapery and curtain specification after Federal Specification CCC-T-191b Method 5903, which is based on AATCC research and development. It states that not only outer fabric, but linings as well need to be self-extinguishing. For certification, manufacturers are required to submit each component fabric.[43]

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[41]California State, ibid. p. 186.

[42]American Association of Textile Chemists & Colorists, Textile Flammability, a Handbook of Regulations, Standards, & Test Methods, (1975), pp. 203-206

[43]American Association of Textile Chemists & Colorists, Textile Flammability Handbook, ibid., pp. 207-209

Boston. This city has been plagued by fire disaster. As a preventative measure it has enacted a flammable decorations code covering such items as curtain and draperies, scenery, and upholstered materials. Flammable decorations are prohibited in public buildings, places of assembly, and in stores.[44]

United States Government Standards and Specifications

National Fire Protection Agency. This agency issued strict voluntary standards for draperies and curtains in 1969. These requirements applied to flame retardant materials used in interior furnishings of buildings such as hotels and hospitals, airplanes and other transport facilities, in protective outdoor coverings such as tarpaulins, and tents. To reveal the stringency of the specifications this agency requires a large size drapery sample 25" by 7' which must hang in folds. Field tests might include retesting of fabric to check that the flame retardancy is still on an acceptable level after continued use.[45]

Military Standards. These will be listed to reveal their scope and the importance of all-encompassing standards.

MIL-STD-1623A (Ships)

Fire Performance Requirements & Approved
Specifications for Interior Finish Materials
& Furnishings (Naval Shipboard Use.)

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[44]Boston, Massachusetts, Flammable Decorations, Article 11 (n.d.)

[45]National Fire Protection Agency, "Fire Test-Flame Resistant Textiles, Films," No. 701 (1969), pp. 5, 9.

MIL-C-24500

Cloth, Drapery, Bunk, Curtain, Slipcovers, & Label, Polyaramid & Polyaramid/Novolid Fiber Blends.[46]

Interim Federal Specifications. These specifications have military and governmental usage, but are frequently adopted for commercial use on a voluntary basis. They are authorized by the National Bureau of Standards.

CCC-C-001703A

Cloth, Drapery, Glass Fiber. The scope includes fire-safe, shrink-safe, woven glass fiber primarily intended for use in drapery fabrication for environmental control of solar radiant heat, light, and glare.

CCC-C-001766

Cloth, Drapery, not Glass. The scope includes woven cloth of animal, vegetable, or synthetic origin.

Mandatory Federal Drapery Standards

What is the status of a mandatory federal drapery standard? The official information is published in a booklet entitled, "Current Status of Federal Flammability Standards on Textile End Uses." All end-uses are rated as those not pursuing any standard to those with an existing federal standard. Draperies are in between these two extremes. They are regarded by this particular source as a likely candidate for

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[46]American Association of Textile Chemists & Colorists, Textile Flammability Handbook, ibid., pp. 75-77.

coverage with some preliminary work already being accomplished.[47] Logically, since the government is investing sums of money in collecting a data base, the case of drapery flammability is being reviewed. If the data interpretation indicates draperies and curtains present unreasonable risk, a standard is in the offing. If that does not occur, the Consumer Products Safety Commission can still be petitioned to develop a national standard. From the date of the publication mentioned, the notice that would begin the process has not been sent through the proper channels.

The National Curtain, Drapery, and Allied Product Association of Market Facts is accumulating data for a possible voluntary standard by American Society for Testing Materials. At present they have no standard regarding the flammability of draperies and curtains. T. Rusk, Chairman of American Society for Testing Materials Committee D13.52.04 on drapery flammability and also a Sears and Roebuck representative endorses the formation of a standard for many reasons. He believes that the proliferation and variety of state and local rules regarding flame retardant draperies in public places, emphasizes the need for the American Society for Testing Materials to eliminate or reduce this confusion. Furthermore, he is of the opinion that a differentiation must be made for specifications for commercial and institutional use.[48]

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[47]James F. Howell, Jr., "Current Status of Federal Flammability Standards on Textile End Uses," Economic & Market Research Service of the National Cotton Council of America, (June 1974), pp. 19-21.

[48]American Society for Testing Materials D13.52, "Task Group-Drapes," Sources & Resources, 1973/9 pp. 5-6.

The National Association of Decorative Fabric Distributors is aware that a standard may be looming.[49] According to various industrial executives, no measures will be taken unless standards are passed. On the other hand, Abe Stanberg, President of Burlington House, a fore-sighted division of Burlington Industries, claims that 20 percent of their draperies are already flame retardant.[50]

The trend is towards more flame retardant fabrics. Drapery standards for commercial, industrial, and institutional use are expanding. Drapery standards for residential use, where most drapery fires occur, are not expanding. However, in hospitals where the danger is most critical, institutional standards are being established for every textile item associated with hospital care including furnishings.[51]

TESTING METHODS

Testing methods have been a source of contention for the textile industry and testing organization since the advent of flammability standards. To duplicate a real life fire and have a standardized economical test procedure is quite a task. Howard Emmons of Harvard University provides insight into the problem of flammability testing. He believes, "there are remarkable discrepancies ... as to what constitutes a fire

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[49] "Flammability Status," Home Furnishings Daily, IIIL, No. 27, February 20, 1975, p. 32.

[50] "Doubt Flammability Retardant Drapes Ready in 5 Years," Home Furnishings Daily, April 10, 1974, p. 16.

[51] J. H. Spritzfaden, "Flame Retardant Regulations Loom for Hospital Care Items," Daily News Record, III, September 21, 1973, 2, 9.

hazard. A scattering of test results may mean that no one knows what characteristics a material should have to be safe. The entire system of a potential fire hazard needs to be rated."[52] A review of literature on flammability testing reveals that it is possible to obtain a variety of results from the same fabric when tested by different methods.[53]

As there is no uniform drapery standard, there is no uniform test method to accompany one. Methods of testing draperies are in the beginning stages; they are not as yet perfected. The ones in existence in the United States are based on the American Association of Textile Chemists and Colorists test method which only applied to flame retardant fabrics. Most drapery and curtain fabric at the present time has not been treated for flame retardancy. The Canadian government has a test for all fabrics that can be ignited which they feel accurately predicts degree of flammability. It is a vertical strip test and would be a little more stringent than our test for untreated fabric, Flammability of Clothing Textiles Test Method 33-1962 of the American Association of Textile Chemists and Colorists.[54]

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[52]Emmons, op. cit., p. 21.

[53]John Anderson, Maureen Grasso, & Martin Gavlak, "Development of a Semi-Restrained FF Test," Textile Chemist & Colorist, VII, No. 6 (June, 1975), 23.

[54]Based on personal correspondence with T. L. Rusk, Chairman of the American Society of Testing Materials Committee on Drapery Flammability, D13.52, February 28, 1975.

This section on testing methods will cover many topics. They are as follows: (1) fabric flammability research needs; (2) multiple layer testing; (3) drapery flammability research.

Fabric Flammability Research Needs

Krasny gave direction to fabric flammability research. He stated the areas that needed further investigation. First, Krasny and Fisher discovered that flame spread was greatly accelerated by even small folds in fabric. Draperies by nature have these chimneys which are accentuated by lining fabrics. To make drapery experimentation realistic, folded, hemmed samples of sufficient length are recommended. Second, Krasny saw the need to simulate action of victims in real life situations. That is, a panic-stricken person tends to run, fanning the flames and suffering severe burns. In light of this, he suggested creating a horizontal air flow with fans. Third, he found relatively few experiments with multiple layers were reported in the literature. He expressed the belief that little is known about the burning characteristics and extinguishability of such systems.[55]

Multiple Layer Testing

The trend in all textile testing is to strive toward the systems approach whereby a fabric of a given end-use is tested in the same way that it would be used. An attempt is made to duplicate all facets of usage. With this goal in mind multiple layer testing is being developed.

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[55]John F. Krasny, "Flammability: Needs for Research," Home Economics Research Journal, II, No. 3 (March, 1974), 160-165.

Research conducted by Keeney for the Southern Regional Research Center revealed the hazards of multiple layer fabric assemblies. The burning characteristics of treated and untreated cotton fabrics were altered by multiple layering and changes in air current. Commonly used flame retardants for cotton were found to be ineffective in maintaining fire resistance characteristics in a two-layer system.[56]

Conner also investigated multiple layer fabric assemblies but in both open and closed configuration using air velocity. She reported multiple layer assemblies burn more rapidly when separated, permitting air circulation around and between layers. Afterflame time increased while afterglow and fabric damage decreased. It is this configuration and these air conditions that most closely resemble circumstances surrounding a drapery ablaze. Conner recommended an investigation into the flammability of drapery and curtain fabric in moving air suggesting that air velocity may be an important factor in this end-use.[57]

Summers' research indicates that it is conceivable that layers of treated and untreated fabrics might be used in household furnishings arrangements. The study showed that if untreated fabric in close

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[56]Pauline E. Keeney, "The Effect of Air Velocity Upon the Burning Characteristics of Multi-layer Fabric Assemblies," Book of Papers, (paper presented at the Technical meeting of American Association of Textile Chemists and Colorists, New Orleans, Louisiana, October, 1974), p. 210.

[57]Gail Conner, "Fire Resistance Characteristics of Selected Multiple Layer Fabric Assemblies in Varying Air Conditions," (unpublished Master's thesis, University of North Carolina at Greensboro, 1974), p. 91.

contact with treated fabric were ignited, it would burn and cause the treated fabric to char resulting in a potential fire hazard.[58]

Gregory and Hotte carried out a preliminary study on drapery and curtain flammability. They investigated burning characteristics in relation to various fibers, constructions, fabric weights, fabric thicknesses, and porosities. They found that the ignition time and rate of burning were directly related to fabric weight. Fabric geometry was an important factor contributing to burning since fabrics with small diameter yarns and low air permeability burn more extensively.

CURRENT STATUS OF FLAME RETARDANT DRAPERIES AND CURTAINS

Flame Retardant Finishes

Cellulosics, cotton, rayon, and flax are considered quite flammable by all means of measurement. At the same time they are the most frequently used fibers in the drapery and curtain market. To combat this many concerns specialize in the effective flame retardant treatment of theatre, scenery, and drapery fabrics using standard flame retardant chemicals.[60] Many companies have newly developed, specialized flame retardant finishes for either drapery fabrics or drapery and upholstery fabrics.

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[58]T. A. Summers, "A Compact Arrangement of Multi-layer Fabrics Burned in a Test Cabinet," Book of Papers, (Paper presented at the Technical meeting of American Association of Textile Chemists and Colorists, New Orleans, Louisiana, October, 1974), p. 220.

[59]J. M. Gregory and George H. Hotte, "Flammability of Fire Resistant Characteristics of Selected Drapery and Curtain Fabrics," Journal of Home Economics, LXIV, No. 1 (March 1972) 37-41.

[60]National Fire Protection Agency, ibid., p. 15.

An example of such a finish is Pyroset CP for cellulosic draperies. Companies associated with this finish are American Cyanamid, Arkansas Chemical, Apex Chemical, and U. S. Borax Company. Its advantages are its low cost and durability to dry cleaning. Many flame retardant finishes for draperies are only durable to dry cleaning. This one is semi-durable to laundering. There is a loss in strength with this finish.[61] Arkansas Chemical Company also produces a finish called Fi-Retard that is solely for drapery fabrics. Companies that specialize in flame retardants for home furnishings fabrics include American Cyanamid, Ciba-Geigy, Dow Chemical, DuPont de Nemours, and B. F. Goodrich.[62]

A recently patented product called Fibercoat is gaining much favor. It is being designed for drapery and other home furnishings fabrics. Fibercoat is expected to meet or surpass current standards withstanding temperatures above 1200° Fahrenheit.[63]

The coated fabrics market for drapery fabrics is very favorable. However, compared with such inert and safe coatings as rubber and PVC, polyurethane, a comparative newcomer to the field, often presents fire hazards and problems of toxicity.[64] There are indications that flame

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[61]R. Bruce LeBlanc, "What's Available for Flame Retardant Textiles," Textile Industries, February, 1974, p. 117.

[62]"A Guide to Flame Retardant Chemicals," America's Textile Reporter/Bulletin, Vol. AT-3, No. 7 (July, 1974), 42.

[63]"FR Fabrics: Growing Demand," America's Textile Reporter/Bulletin, Vol. AT-1, No. 7 (July, 1974), 40.

[64]J. C. Smith, "Coating of Fabrics," Textiles, by Shirley Institute, IV, No. 1 (January, 1975), 23.

retardant additives in the backing can increase the flame retardance of the whole system.[65]

Flame Retardant Fibers

Research and development is in an era of inherently flame retardant fibers. Many fibers have been developed and are now being engineered to specific end-uses. In draperies and curtains the following fibers are meeting with success: Modacrylics, FR rayon, FR acetate and triacetate, FR polyester (A-tell), PVC and PVA (Rhovyl, Leavil, and Cordelon.)[66] According to Howard, modacrylic is the most successful fiber for drapery fabric. Saran makes a very successful warp yarn.[67]

Whether flame retardancy is in a finish or fabric form is of relatively little importance. More important is the fact that it is present and will perform effectively. A critical issue is that draperies and curtains can continue to be made with a variety of fibers and constructions that the consumer desires, can still be aesthetically pleasing and functional, and yet will not be the cause of added danger in our surroundings.

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[65]Charles C. Yeager and Jay C. Chapin, "A Systems Approach to Flame Retardancy," Textile Chemists & Colorists, IV, No. 4 (April, 1972) 40.

[66]H. C. Nixon, "Fabrics for Home Furnishings-A Novelty Yarn Spinner's Approach," Sources & Resources, 1974/2 p. 17.

[67]R. E. Howard, "Flame Retardant Drapery Fabrics," Textile Industries, CXXXI, No. 7 (July, 1967), 104.

CHAPTER III

PROCEDURE

This study was undertaken as a contribution to the Southern Regional Research Project S-86, sponsored by the Cooperative State Research Service of the United States Department of Agriculture. The research has been conducted by Home Economics research personnel associated with the Agriculture Experiment Stations of states interested in fabric flammability. The states actively participating include Alabama, California, Colorado, Louisiana, Minnesota, North Carolina, and Tennessee. This thesis will supplement Objective 2 of the Regional Research which is concerned with the effects of air velocities on the burning characteristics of single and multiple layer arrangements of fabrics.[1]

FABRICS SELECTED FOR EXPERIMENTATION

The fabrics were selected from retail establishments as representative of curtain and drapery fabrics available to the consumer. They were chosen on the basis of their cellulosic fiber content and included: (1) 100 percent cotton, (2) 100 percent linen, (3) 100 percent rayon, and (4) cotton and rayon blends. Each of the above

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[1]Technical Committee, Southern Regional Research Center, "Manual of Procedures: Performance of Selected Fabrics Treated with Flame Retardant Finishes" (New Orleans: Cooperative State Research Service, 1973), p. 3. (Mimeographed.)

groups included fabrics of medium and heavy weight. Fabrics of these two weights could be used with a lining. These fabrics formed the first layer in the two layer fabric assembly.

The second layer of the fabric assembly was the lining fabric. These fabrics were selected as representative of lining fabric available to the consumer. They also were chosen on the basis of their cellulosic fiber content and included: a 100 percent cotton sateen and a 100 percent acetate thermal lining.

TESTING OF BURNING CHARACTERISTICS

Preparation of Test Samples

All fabrics for experimentation were cut into 3 by 10 inch pieces with the longer dimension in the warp direction. The two layers were assembled with the first layer consisting of the drapery fabric and the second layer consisting of lining fabric.

In order to investigate two layer fabric assemblies with spacing between layers, the frames were modified slightly by the use of metal strips (1 x 10 x 1/8 inches) conforming to the sides of the frame. The two layers, one drapery fabric and one lining fabric, were placed between the frame and the strips. A diagram of the assembly is shown in Figure 1.

In the fabric assembly the layers were kept separated by the metal strips permitting a 1/8 inch air space between layers. The resulting fabric assembly was placed so that the flame would have equal opportunity to ignite both layers at once.

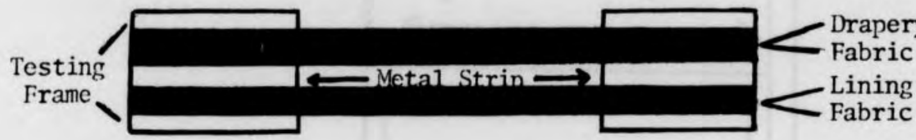

Figure 1

Diagram of Open Fabric Assembly
in Cross Section

Description of Test Cabinet

The fire resistance tester used in this study was adapted from the standard fire resistance instrument accepted by the American Association of Textile Chemists and Colorists for use in testing the fire resistance of textile fabrics (AATCC 34-1969).[2] The equipment was specially designed by a former graduate student at the University of North Carolina at Greensboro and built to specification for testing burning characteristics of fabrics in varying velocities of air. The equipment is shown in Figure 2.

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[2]American Association of Textile Chemists and Colorists, Technical Manual, Vol. 49 (North Carolina: American Association of Textile Chemists and Colorists, 1973), p. 205.

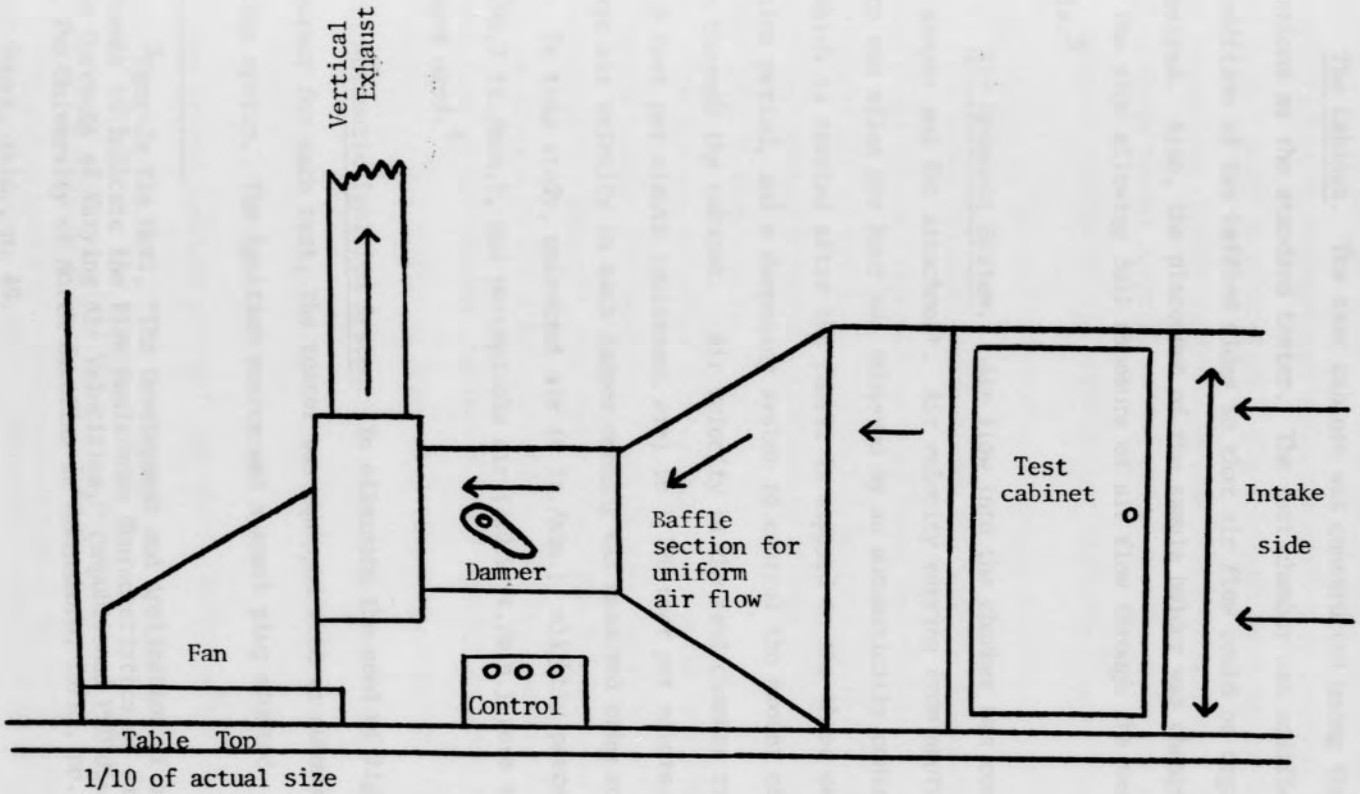

Figure 2

Diagram of Fire Resistance Testing Equipment

The Cabinet. The test cabinet was constructed using the same dimensions as the standard tester. The test chamber was modified by the addition of two baffled sides so that air flow could be regulated if desired. Also, the placement of the sample holder was changed to face the side allowing full exposure of air flow through the test sample.[3]

Air Movement System. Air flow into the chamber was controlled by a damper and fan attachment. Air velocity varying from approximately one to ten miles per hour was achieved by an automatically controlled fan which is started after the fabric is exposed to the three second ignition period, and a dampening system to control the amount of air drawn through the cabinet. Air velocity in the test chamber ranges from 0 feet per minute (quiescent air) to 1,700 feet per minute. The average air velocity in each damper opening was measured using an anemometer. In this study, quiescent air (0 ft./min.), slightly perceptible air (96.7 ft./min.), and perceptible air (229.9 ft./min.) were the averages used.[4]

Automatic Ignition System. To eliminate the need of lighting the burner for each test, the tester was equipped with an automatic ignition system. The ignition source was a spark plug mounted

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[3]Yang-Ja Kim Mori, "The Development and Application of an Instrument to Indicate the Fire Resistance Characteristics of Fabrics in Air Currents of Varying Air Velocities," (unpublished PhD dissertation, The University of North Carolina at Greensboro, 1972), pp. 37-40.

[4]Mori, ibid., p. 49.

perpendicular to the gas burner. When the ignition button was pressed, the solenoid valve released gas which the spark plug ignited. The flame height could be controlled. The automatic ignition system has a timer permitting uniform ignition periods from 0-30 seconds. For this study a three second ignition period was used. The timer cut off the gas supply at the end of the three second ignition.[5]

Burning Procedure

The basic procedure followed was the American Association of Textile Chemists and Colorists Vertical Flame Test Method 34-1969 for the flammability of fabrics. This method has been incorporated into the Federal Test Method Standard 191, Flame Resistance of Cloth; Vertical (Method 5903.2) from July 9, 1971.

The cut and assembled fabrics were coded as to consecutive number, random number, air velocity, fiber content, fabric weight, type of lining fabric (if present), and replication. The fabrics were not placed in an oven at 105°F for one-half hour as the standard indicates for the flow of air through the fabric would rapidly increase the moisture content of the sample to some level beyond the bone dry state.[6] The samples were put into a dessicator for a half hour for uniform humidity. The flame was adjusted to a height of one and one-half inches and was placed so that both layers could ignite simultaneously during the three second ignition period. For those fabrics tested in moving

[5]Mori, ibid., p. 51.

[6]Based on personal correspondence with T. L. Rusk, chairman of the American Society of Testing Materials' Committee on Drapery Flammability, D13.52, Feb. 28, 1975.

air, the fan was started immediately after the ignition period, drawing air of the specified velocity into the test cabinet. The duration of time that the sample supported combustion following the ignition period was measured as seconds of afterflame. The seconds of afterglow were the time after the flaming ceased to the time the glowing ended. The air current continued to circulate through the test cabinet when both the afterflame and afterglow times were being measured.

Once the afterflaming and afterglowing had ceased, the samples were removed from the holder and measured for fabric damage. For this study, a measurement of fabric damage was substituted for the char length of the standard procedure because of the tendency of the two layers to fuse, rendering an accurate char length measurement impossible. Fabric damage as defined by this investigation was the extent to which the fabric is rendered unusable due to discoloration, fusion, or any other abnormal occurrence after the fabric has been tested. The fabric damage was measured to the nearest 0.01 of an inch on the face side of the first layer of fabric assembly.

Treatment of Data

The two layer fabric assemblies were observed during burning to note any unusual burning characteristics in the open fabric position. Unusual occurrences were noted to be used to supplement the statistical treatment of data.

The data recorded for afterflame, afterglow, and fabric damage were analyzed using an analysis of variance. A 2 x 4 x 3 x 3 factorial design with 4 replications was used. A detailed explanation of experimental factors is shown in Table 1. All possible fabric combinations for both medium and heavy weight fabrics are shown in Tables 2 and 3 respectively.

Table 1

Experimental Factors

Fiber Content of Drapery Fabrics
1. 100% Cotton
2. 100% Linen
3. 100% Rayon
4. Cotton/Rayon Blend

Fabric Weight
1. Medium (Under 8 oz./yd.^{2})
2. Heavy (Over 8 oz./yd.^{2})

Fiber Content of Lining Fabrics
1. No lining
2. 100% Cotton Sateen Lining
3. 100% Acetate Thermal Lining

Air Velocity
1. Quiescent Air (Control)
2. 97 Feet/Minute (Approximately 1 mile per hour)
3. 230 Feet/Minute (Approximately 3 miles per hour)

Table 2

Flow Chart of Statistical Treatment
for Medium Weight Fabric

- Medium Weight Fabrics
  - 100% Cotton
    - No Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Low Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Perceptible Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining
  - 100% Rayon
    - Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining
  - 100% Linen
    - Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining
  - Cotton/Rayon Blend
    - Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining

Table 3

Flow Chart of Statistical Treatment
for Heavy Weight Fabric

- Heavy Weight Fabrics
  - 100% Cotton
    - No Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Low Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Perceptible Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining
  - 100% Rayon
    - Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining
  - 100% Linen
    - Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining
  - Cotton/Rayon Blend
    - Air Velocity 1
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 2
      - Unlined
      - Sateen Lining
      - Thermal Lining
    - Air Velocity 3
      - Unlined
      - Sateen Lining
      - Thermal Lining

CHAPTER IV

DATA ANALYSES AND DISCUSSION OF RESULTS

This chapter describes the properties of the experimental fabrics and their burning characteristics in varying velocities of air. The data related to each experimental factor and interactions of factors are presented. A description of observations during testing is also included.

PROPERTIES OF THE SELECTED CELLULOSIC FABRICS

A laboratory analysis of the properties of the selected cellulosic fabrics was carried out. The results of this analysis for properties of the experimental drapery fabrics are shown in Table 4. Properties of the experimental lining fabrics are shown in Table 5.

The fabrics chosen were representative of the curtain and drapery market. The drapery and curtain fabrics were purchased from the retail market in the manner of the average consumer. The eight fabrics selected for experimentation were of four fiber contents, cotton, linen, rayon and a cotton and rayon blend. Fiber contents were selected on the basis of the label applied by the manufacturer. The labeled fiber contents were not completely accurate. This was true of two of the fabrics selected. Both were purchased from a different retail establishment. One was purchased from a specialty drapery and upholstery fabric shop and the other from a discount fabric house. A customer purchasing these fabrics would have been misled. Those purchased at a large department store were accurately labeled.

Table 4

Properties of Experimental Drapery Fabrics

Properties	Fabric 1	Fabric 2	Fabric 3	Fabric 4
		Medium Weight Drapery Fabrics		
Fiber Content	Cotton	Linen	Rayon	Blend
Warp	Cotton	Cotton	Rayon	Cotton
Filling	Cotton	Flax	Rayon	Cotton & Rayon
Thread Count				
Warp	69	46	76	75
Filling	36	34	35	30
Thickness (.001")	.018	.017	.014	.033
Weave	Plain	Plain	Plain (Rib)	Jacquard
Weight (oz./yd.^{2})	6.20	6.89	3.79	7.61
		Heavy Weight Drapery Fabrics		
Fiber Content				
Warp	Cotton	Flax	Acetate	Cotton & Rayon
Filling	Cotton	Flax	Rayon	Cotton & Rayon
Thread Count				
Warp	82	28	71	42
Filling	25	23	58	38
Thickness (.001")	.026	.022	.019	.036
Weave	Plain (Basket)	Plain	Twill	Twill
Weight (oz./yd.^{2})	8.24	8.18	6.17	12.71

The two fabrics with mislabeled fiber contents were the medium weight linen fabric and the medium weight rayon fabric. The linen fabric had a cotton warp and the rayon fabric had an acetate warp. All fabrics were of high cellulosic content and were consequently used as purchased. These two fabrics are referred to as 100 percent linen and 100 percent rayon since they were labeled as that fiber content. The true fiber contents were noted.

Fabrics were selected on the basis of weight as well as fiber content. Each of these four fiber contents were in two weights, medium and heavy weights. Because fabrics were purchased from the retail market, the categories of medium and heavy weight fabric could only be estimated. They are not absolute categories. The fabrics as analyzed generally fall into the two categories of under 8 oz./yd.^{2} and over 8 oz./yd.^{2} Fabric 3 in each group being of rayon and a rayon/acetate blend were slightly lighter in weight than the other fabrics in each group.

All fabrics were firmly woven, five being of plain weave, two of twill, and one of jacquard weave. Fabrics in each group differed in thread counts and thickness.

The fabrics chosen probably had been finished like other cellulosic drapery fabrics. No attempt was made to analyze these treatments. The fabrics had already been printed or dyed.

The lining fabrics were also representative of what is commonly used in custom draperies. However, they were chosen as distinctly different lining fabrics. As shown in Table 5, they are different in nearly all characteristics including fiber content, weave, and thread count. They were both relatively lightweight fabrics.

Table 5

Properties of Experimental Lining Fabrics

	Lining Fabrics	
Properties	Lining 2	Lining 3
Fiber Content	100% Cotton	100% Acetate
Thread Count		
Warp	60	82
Filling	87	62
Thickness (.001")	.011	.008
Weave	Sateen	Plain
Weight (oz./yd.^{2})	3.45	3.17

ANALYSIS OF DATA

The data collected on afterflame and afterglow were analyzed according to a 2 x 4 x 3 x 3 analysis of variance using the Statistical

Analysis System (SAS) computer package.[1] It was originally planned to collect and analyze data on fabric damage. However, only 3 of 288 samples did not burn the entire length. Two of these were heavy weight rayon fabrics and one was a heavy weight cotton/rayon blend with a cotton lining. The rayon fabrics burned 5.5 and 8.4 inches of the 10 inch sample. The other two replications burned the entire length. The blend had a fabric damage measurement of 2.06 inches. The other three replications burned the entire length. It is likely that this was irregular behavior. Because so few incidents of measurable fabric damage occurred and all other samples burned the entire length, afterflame and afterglow times were the burning characteristics that were analyzed statistically. The results of the analysis of variance of afterflame time and afterglow time for all experimental factors are shown in appendices A and B.

As indicated there was a significant difference in air velocity on both afterflame and afterglow times. The mean afterflame time and afterglow time for the three air velocities are shown in Table 6. There was an indirect relationship between the effect of air velocity on afterflame and afterglow time. As air velocity increased, afterflame time increased and afterglow time decreased.

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[1]Jolyane Service, Anthony Barr, and James Goodnight, A User's Guide to Statistical Analysis System, (Raleigh: North Carolina State University), August 1972.

Table 6

Mean Afterflame and Afterglow Times in Various Air Velocities

Air Velocity	Afterflame (Seconds)*	Afterglow (Seconds)*
Air Velocity 1 (0 ft./min.)	39.53	185.91
Air Velocity 2 (97.6 ft./min.)	64.05	60.45
Air Velocity 3 (230 ft./min.)	120.33	39.22

*Significant at the .01 level.

The analysis of variance tables, appendices A and B, also show that there was a significant difference in fabrics of four fiber contents on both the afterflame and afterglow times for the fabrics in each fiber group. The mean difference in afterflame and afterglow are shown in Table 7. Rayon has the lowest mean afterflame time at 38.03 seconds and the cotton and rayon blend had the highest at 107.70 seconds. The blend had the highest mean afterglow time of 151.87 seconds. Linen had the lowest mean afterglow time at 51.09 seconds.

Table 7

Mean Afterflame and Afterglow Times of Drapery Fabrics

Fabric	Afterflame (Seconds)*	Afterglow (Seconds)*
Cotton	77.93	80.43
Linen	74.90	51.09
Rayon	38.03	97.38
Blend	107.70	151.87

*Significant at the .01 level.

There was a significant difference in the two fabric weights for both afterflame and afterglow. The medium weight fabric had a mean afterflame time of 56.8 seconds and a mean afterglow time of 56.7 seconds. The heavy weight fabric had a mean afterflame of 92.4 seconds and a mean afterglow time of 133.7 seconds. The heavy weight fabrics burned longer and extinguished themselves more slowly than the medium weight fabrics as shown in Table 8.

Table 8

Mean Afterflame and Afterglow Times
for Fabric Weight

Weight	Afterflame (Seconds)*	Afterglow (Seconds)*
Weight 1 (under 8 oz./yd.^{2})	56.83	56.72
Weight 2 (over 8 oz./yd.^{2})	92.45	133.67

*Significant at the .01 level

Introducing a lining fabric caused no significant differences in the afterflame and afterglow times. The burning times were very similar regardless of the type of lining or the weight of the drapery fabrics. The only factor causing significant change in burning with lined draperies was air velocity. The mean afterflame and afterglow times for lining fabrics are shown in Table 9.

There was a significant interaction between Air Velocity and Fabric on both the afterflame and afterglow variables. The means are reported in Table 10. Graphs of the means are shown in Figures 3 and 4.

Table 9

Mean Afterflame and Afterglow Times of Lining Fabrics

Lining	Afterflame (Seconds)	Afterglow (Seconds)
No lining	74.39	105.20
Cotton Lining	77.75	97.03
Acetate Lining	71.77	83.34

Table 10

Burning Characteristics of Outer Layer Fabrics in Varying Air Conditions (AV x F N = 92)

Fabric Types	Air Velocity 1 (0 ft./min.)	Air Velocity 2 (97 ft./min.)	Air Velocity 3 (230 ft./min.)
		Afterflame (Seconds)*	
Cotton	44.40	59.18	130.20
Linen	35.75	53.92	135.03
Rayon	25.18	36.68	52.20
Blend	52.79	106.40	163.90
		Afterglow (Seconds)*	
Cotton	164.23	54.70	22.33
Linen	98.55	35.65	19.07
Rayon	180.72	62.03	49.38
Blend	300.11	89.40	66.09

*Significant at the .01 level.

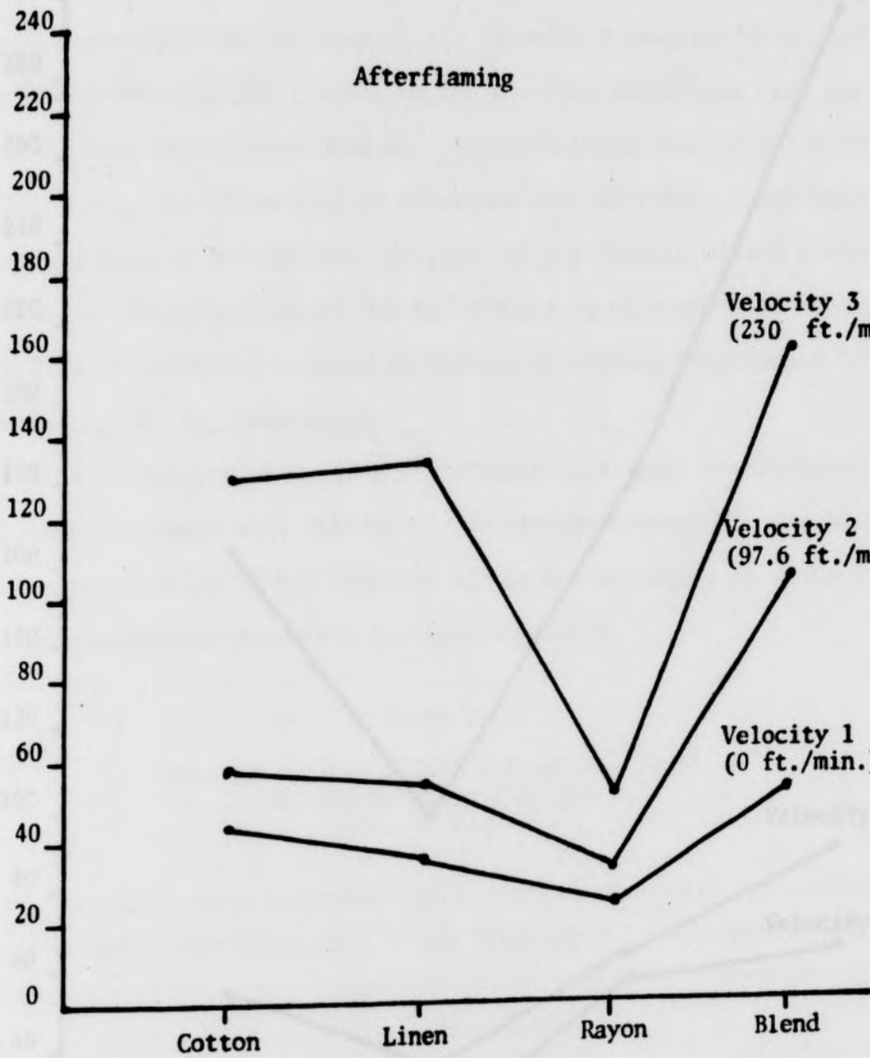

Figure 3

The Afterflame Time of Fabrics
in Varying Air Conditions

(AV x F N = 92)

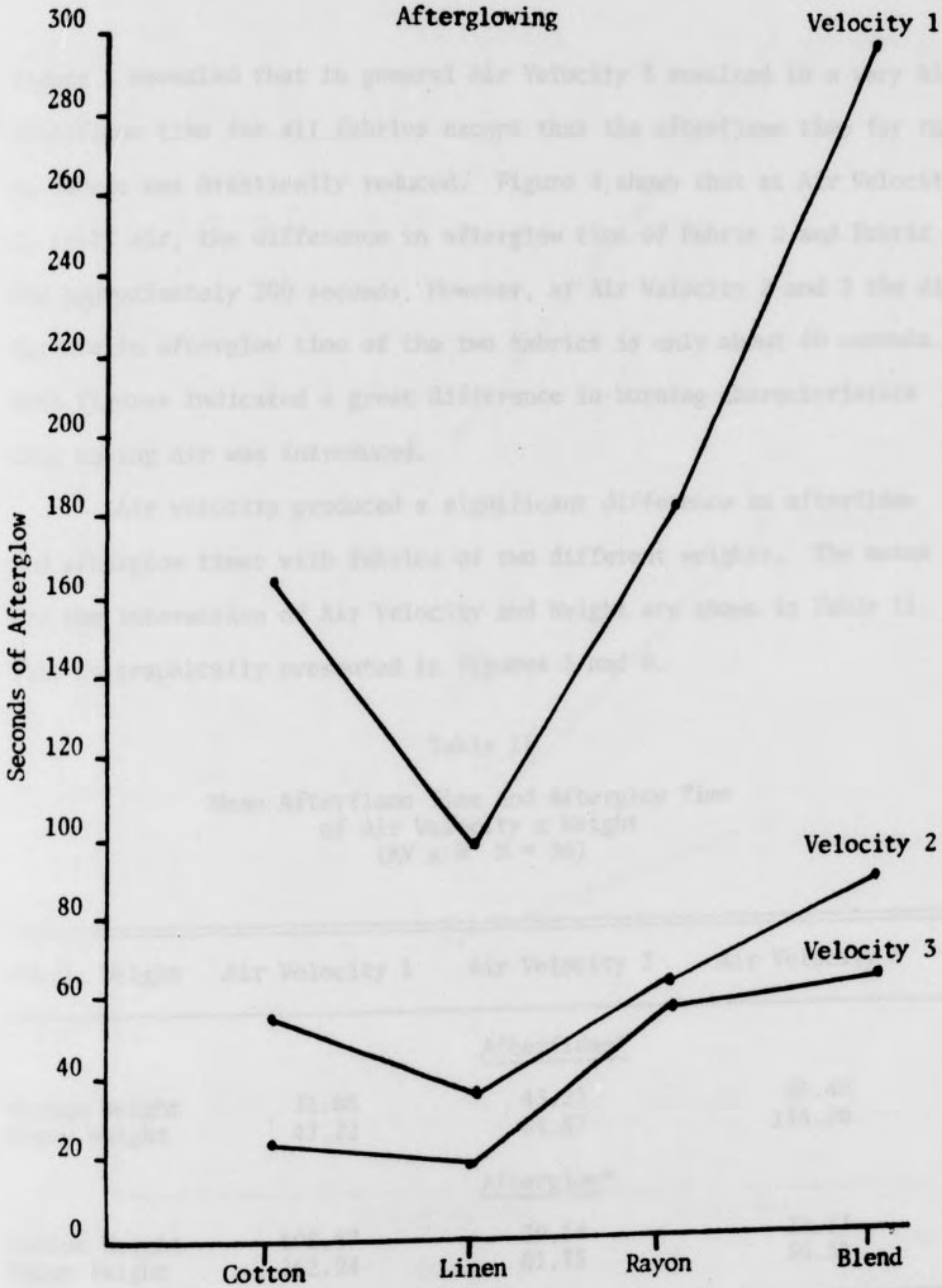

Figure 4

The Afterglow Time of Fabrics
in Varying Air Conditions

(AV x F N = 92)

Figure 3 revealed that in general Air Velocity 3 resulted in a very high afterflame time for all fabrics except that the afterflame time for rayon fabric was drastically reduced. Figure 4 shows that at Air Velocity 1, still air, the difference in afterglow time of Fabric 2 and Fabric 4 was approximately 200 seconds. However, at Air Velocity 2 and 3 the difference in afterglow time of the two fabrics is only about 40 seconds. Both figures indicated a great difference in burning characteristics when moving air was introduced.

Air velocity produced a significant difference in afterflame and afterglow times with fabrics of two different weights. The means for the interaction of Air Velocity and Weight are shown in Table 11. This is graphically presented in Figures 5 and 6.

Table 11

Mean Afterflame Time and Afterglow Time
of Air Velocity x Weight
(AV x W N = 96)

Fabric Weight	Air Velocity 1	Air Velocity 2	Air Velocity 3
		Afterflame*	
Medium Weight	31.85	43.22	95.40
Heavy Weight	47.22	84.87	145.26
		Afterglow*	
Medium Weight	108.87	39.14	22.13
Heavy Weight	262.94	81.75	56.31

*Significant at .01 level.

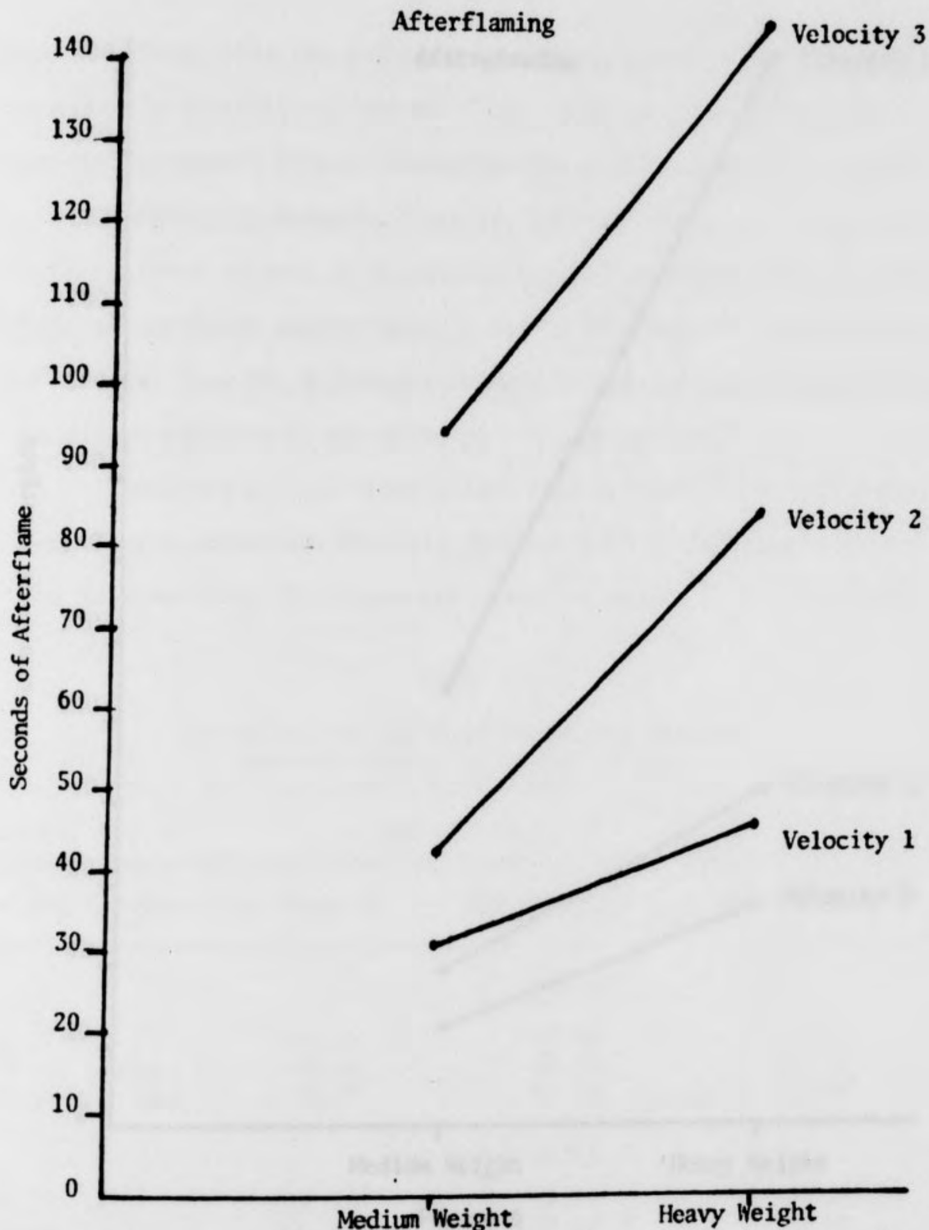

Figure 5

Mean Afterflame Time of Air Velocity
x Fabric Weight

(AV x W   N = 96)

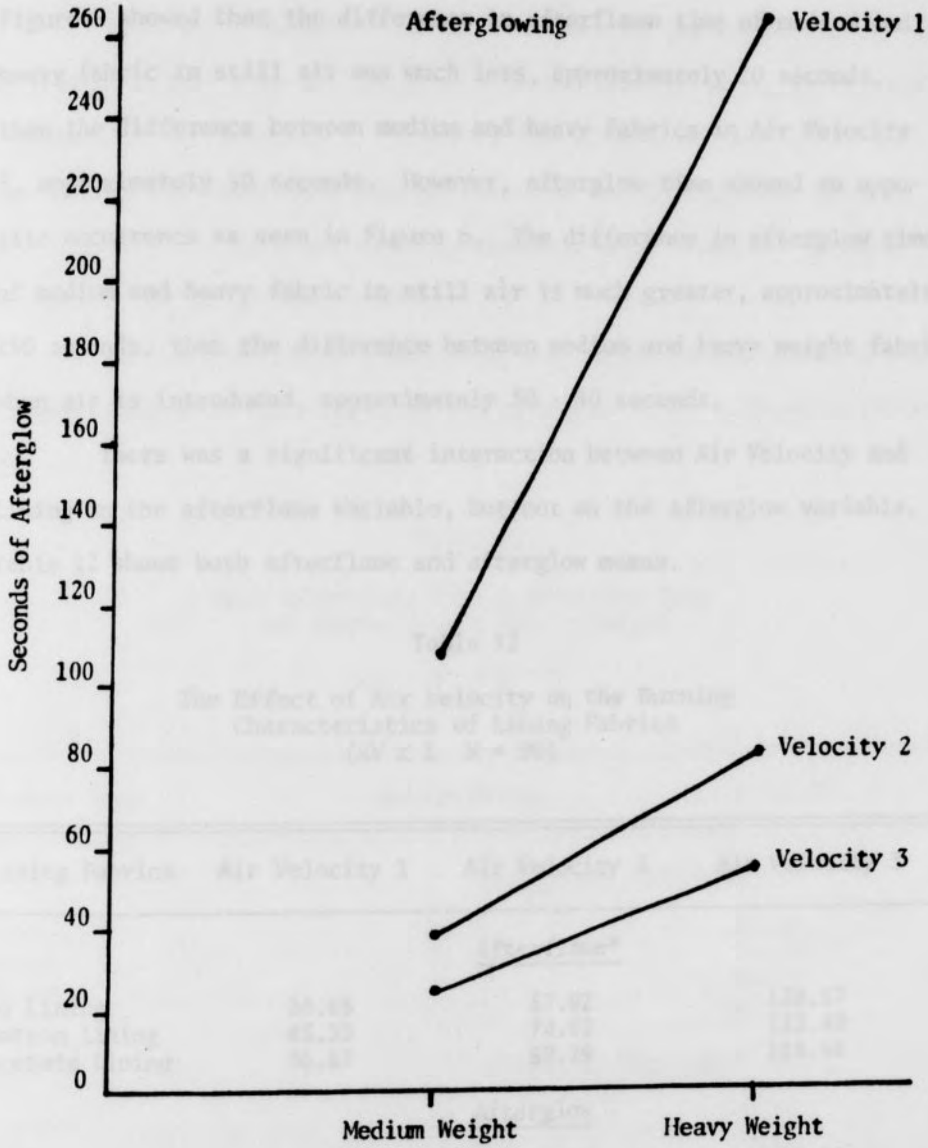

Figure 6

Mean Afterglow Time of Air Velocity x Fabric Weight

(AV x W N = 96)

Figure 5 showed that the difference in afterflame time of medium and heavy fabric in still air was much less, approximately 20 seconds, than the difference between medium and heavy fabrics in Air Velocity 3, approximately 50 seconds. However, afterglow time showed an opposite occurrence as seen in Figure 6. The difference in afterglow time of medium and heavy fabric in still air is much greater, approximately 150 seconds, than the difference between medium and heavy weight fabrics when air is introduced, approximately 30 - 40 seconds.

There was a significant interaction between Air Velocity and Lining on the afterflame variable, but not on the afterglow variable. Table 12 shows both afterflame and afterglow means.

Table 12

The Effect of Air Velocity on the Burning Characteristics of Lining Fabrics (AV x L N = 96)

Lining Fabrics	Air Velocity 1	Air Velocity 2	Air Velocity 3
		Afterflame*	
No Lining	36.68	57.92	128.57
Cotton Lining	45.35	74.42	113.49
Acetate Lining	36.57	59.79	118.94
		Afterglow	
No Lining	206.13	72.89	36.58
Cotton Lining	191.65	57.02	42.43
Acetate Lining	159.93	51.43	38.65

*Significant at .01 level.

Figure 7 graphically shows afterflame of the cotton lining was higher than that with no lining or with the acetate lining at Air Velocity 1 or Air Velocity 2. However, the afterflame time of the cotton lining was lower than that of the other two lining conditions at Air Velocity 3. This was the only instance when lining was a significant factor in the entire study.

The interaction of Fabric Type and Fabric Weight produced significant differences in afterflame and afterglow times as seen in Table 13.

Table 13

Mean Afterflame Time x Afterglow Time of Fabric Type x Fabric Weight

(F x W N = 72)

Fabric Type	Medium Weight	Heavy Weight
	Afterflame (Seconds)*	
Cotton	56.36	99.49
Linen	75.61	74.20
Rayon	29.81	46.24
Blend	65.51	149.87
	Afterglow (Seconds)*	
Cotton	40.46	120.39
Linen	51.49	50.69
Rayon	48.76	145.99
Blend	86.14	217.59

*Significant at .01 level.

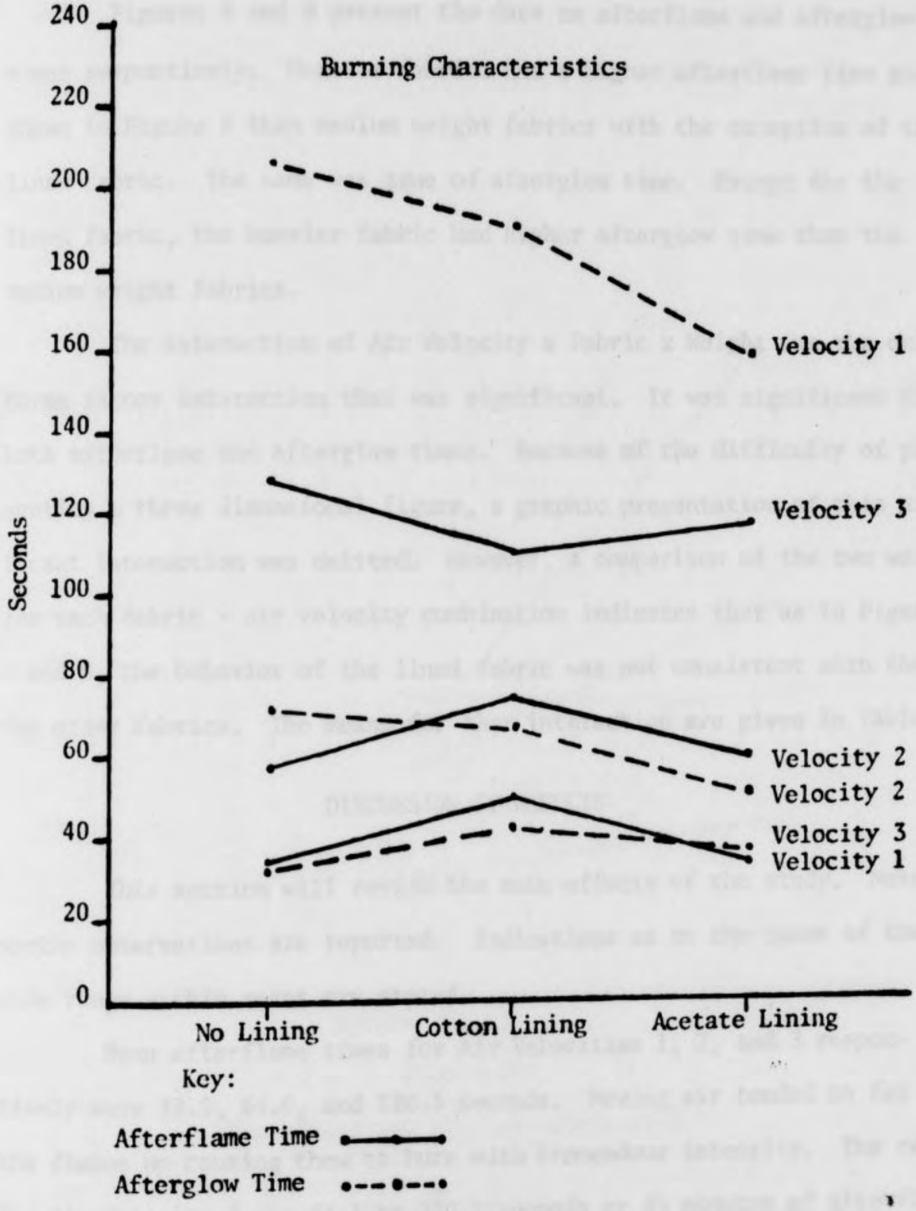

Figure 7

Burning Characteristics of Lining Fabrics
in Varying Air Conditions

(AV x L N = 96)

Figures 8 and 9 present the data on afterflame and afterglow times respectively. Heavier fabrics had a higher afterflame time as shown in Figure 8 than medium weight fabrics with the exception of the linen fabric. The same was true of afterglow time. Except for the linen fabric, the heavier fabric had higher afterglow time than the medium weight fabrics.

The interaction of Air Velocity x Fabric x Weight was the only three factor interaction that was significant. It was significant for both afterflame and afterglow times. Because of the difficulty of presenting a three dimensional figure, a graphic presentation of this significant interaction was omitted. However, a comparison of the two weights for each fabric - air velocity combination indicates that as in Figures 8 and 9, the behavior of the lined fabric was not consistent with that of the other fabrics. The means for that interaction are given in Table 14.

DISCUSSION OF RESULTS

This section will review the main effects of the study. Noteworthy observations are reported. Indications as to the cause of the wide range within means are stated.

Mean afterflame times for Air Velocities 1, 2, and 3 respectively were 39.5, 64.0, and 120.3 seconds. Moving air tended to fan the flames up causing them to burn with tremendous intensity. The range for Air Velocity 3 was 34.1 to 270.1 seconds or 4½ minutes of afterflame time. Such long afterflame and afterglow times do generally not occur in still air. The reverse effect occurred for afterglow times. Mean seconds of afterglow for Air Velocities 1, 2, and 3 were 185.9, 60.4,

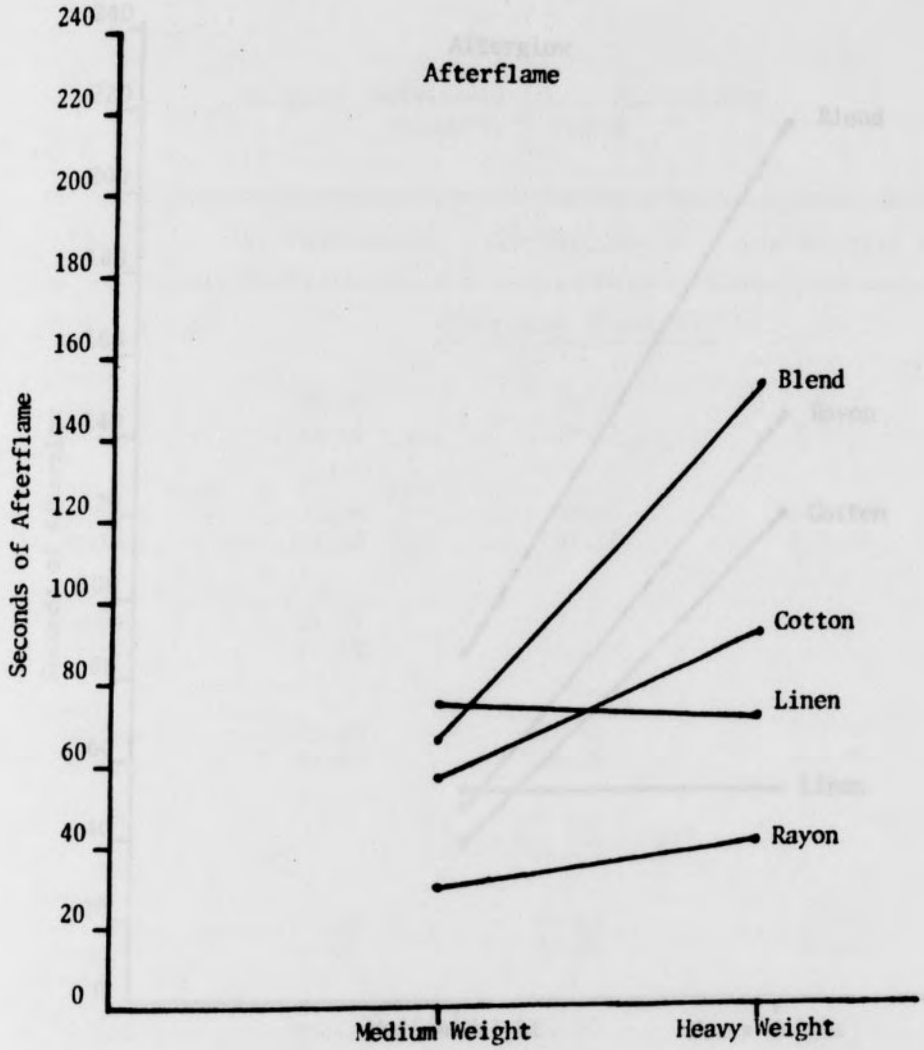

Figure 8

Mean Afterflame Time of Fabric Type
x Fabric Weight

(F x W N = 72)

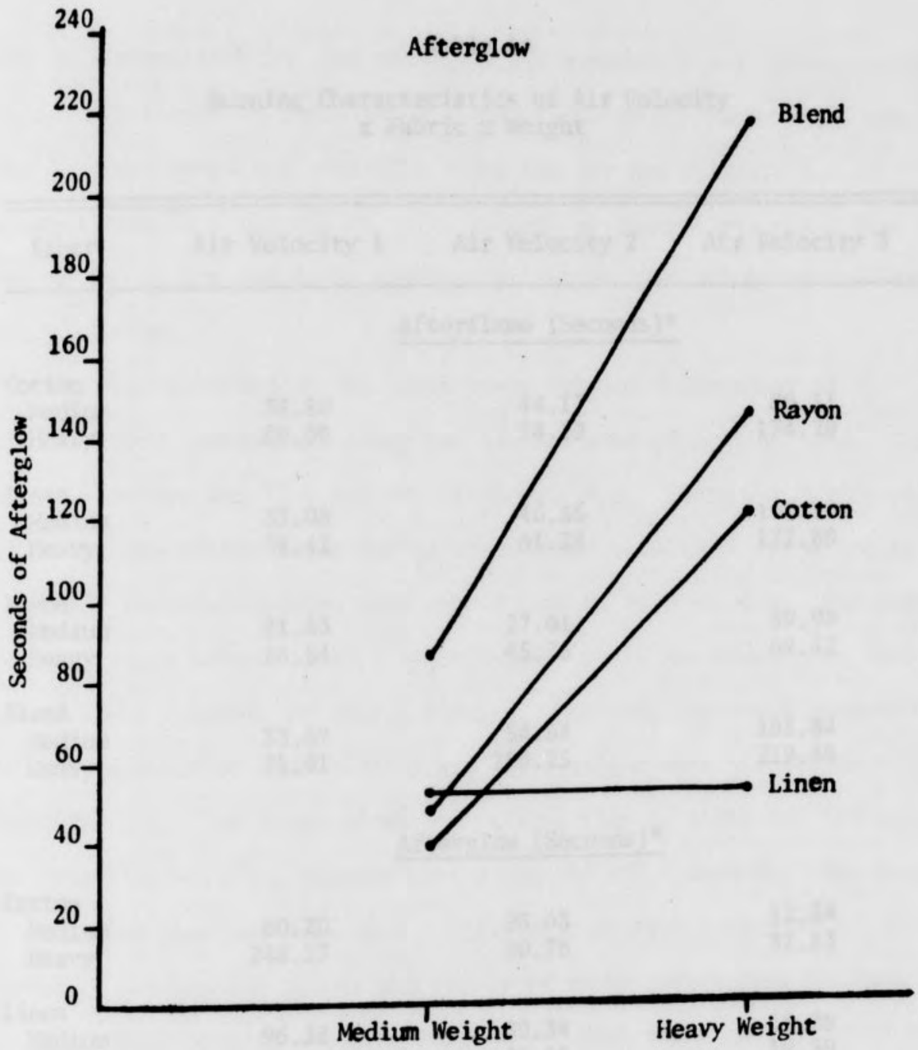

Figure 9

Mean Afterglow Time of Fabric Type
x Fabric Weight

(F x W N = 72)

Table 14

Burning Characteristics of Air Velocity x Fabric x Weight

Fiber	Air Velocity 1	Air Velocity 2	Air Velocity 3
		Afterflame (Seconds)*	
Cotton			
Medium	38.80	44.17	86.11
Heavy	50.00	74.19	174.28
Linen			
Medium	33.08	46.56	147.18
Heavy	38.42	61.28	122.89
Rayon			
Medium	21.83	27.61	39.98
Heavy	28.54	45.75	64.42
Blend			
Medium	33.67	54.54	108.84
Heavy	71.91	158.25	219.46
		Afterglow (Seconds)*	
Cotton			
Medium	80.20	28.65	12.54
Heavy	248.27	80.76	32.13
Linen			
Medium	96.38	39.34	18.76
Heavy	100.73	31.96	19.39
Rayon			
Medium	93.35	32.71	20.22
Heavy	268.10	91.35	78.54
Blend			
Medium	165.57	55.87	37.00
Heavy	434.66	122.94	95.19

*Significant at the .01 Level.

and 39.2 respectively. The afterglow was apparently not strong enough to sustain itself in turbulent air conditions as it did in still air. The greatest range for afterglow times was for Air Velocity 1. It spanned from 72.1 seconds to 457.0 seconds or over 7½ minutes. This may be due to the two layer combination rather than solely to the still air condition.

When considering the outer layer fabrics independent of all other factors, cotton and linen had similar mean afterflame time. The mean for cotton was 77.9 and for linen was 74.9. There was a wide range of actual afterflame times due to varying air velocity. Rayon had an unusually rapid afterflame time with a mean of 38.0 seconds. One sample was completely burned in 15.1 seconds under still air conditions, but glowed 130.1 seconds, or over 2 minutes. However, the worst example of burning in terms of both results and observations were the cotton/rayon blend fabrics. The range of the afterflame time of these two fabrics was from 27.1 to 270.1 seconds with a mean of 107.7 seconds. The range of afterglow time was from 30.7 - 457.0 seconds with a mean of 151.9 seconds. The lapping flames and clouds of smoke coming from the burning of these small samples appeared hazardous. Both rayon and rayon/cotton blends, particularly those with a lining, appeared to be the greatest fire hazard.

Fabric weight appeared to be a very strong factor in influencing the burning characteristics. When weight was one of the factors, there was often a significant difference. This is undoubtedly because a fuel is required to support combustion. In this case the fuel is the cellulosic fabric. With more fabric the fire intensified. This is pointed out in the mean afterflame time of 92.4 seconds and a mean afterglow time of 133.7 seconds for the heavy weight fabric. The mean afterflame time for heavy weight fabric was only approximately one-half of the mean for the medium weight fabrics. The mean afterglow time was only approximately one-third of that for medium weight fabrics.

The most unexpected results of the study were related to the lining variable. It was not significant as a single variable or in any 3 factor interaction. It was significant in only one interaction with air velocity, afterflame time. Mean afterflame times were very similar, between 71.7 and 77.7 seconds, for all three lining conditions. Mean afterglow times had much more variability. The mean afterglow time was highest with no lining at 105.2 seconds. The mean afterglow time for the cotton lining decreased to 97.0. It decreased further to 83.3 with the acetate lining. This indicates that the self-extinguishing ability of acetate helped to decrease the burning characteristics to a lower but still unacceptable level. Acetate was the only fiber in the study that melted, blistered, and dripped instead of charring. There were several instances where the flaming drips of the acetate were strong enough to reignite the drapery fabric or other sections of the acetate lining itself.

Regardless of the fact that the presence of lining did not affect burning times, it did affect the way the sample burned. This was not reflected in actual afterflame and afterglow times. Perhaps another method of testing flammability would have reflected this more than the properties measured in the test procedure used. A chimney effect was often produced. That is, smoke and flames moved vertically between the two fabric layers and often streamed from the top of the sample.

Even though both drapery and lining fabrics were ignited simultaneously, the lining often burned much more quickly. At times, particularly with the acetate lining, the entire lining would burn and then a second stage of burning would begin with the drapery fabric. An explanation for this would be differences in fabric weights. The acetate, being such a lightweight fabric, burned quickly. The cotton lining burned more slowly than the acetate, but often more quickly than the drapery fabrics. The exception to these statements would be the medium weight rayon drapery fabrics. It was a very lightweight fabric and was likely to burn quickly like the lining fabrics. The rapid burning of the lining fabric, in effect, caused a change from a two layer fabric assembly to a one layer fabric assembly. As a result there was no significant difference in lining fabrics. On occasion the flame would travel up the lining, over the top of the sample, and down the front of the drapery. Lining does have an obvious effect on burning that does not reveal itself in the data.

Lining is also the cause for other irregular burning behavior. For example, a rayon or cotton-rayon blend combined with an acetate lining would cause a great deal of sparking. This explosive behavior is likely to catch other items on fire and cause injury to eyes, skin, and hair. It is this type of behavior that originated flammability legislation. Also, with drapery lining added, the flame travel is no longer predictable. When a single layer of fabric was burned, it was likely that the flame spread was in a vertical path. With lining introduced the flame spreads in a number of ways. It can be sporadic especially when air velocity is introduced. At times it is horizontal, perhaps due to fabric construction. At other times it spreads in widening circles. Nevertheless, it is anything but what is normally observed in flammability studies.

There were other interesting observations and irregular behavior that were not necessarily due to the presence of lining. A key factor in a fire is smoke. Smoke and fumes were of incredible volume and intensity particularly when two layers were involved. The large amount of smoke coming from one burning and at times from one bit of afterglow was most unusual. It is quite possible that some of these fumes are of the toxic variety. There was another interesting observation concerning the smoke. The changeover from afterflame to afterglow also seemed to repeatedly cause a change in smoke production. If smoking occurred during the afterflame, it often diminished or stopped entirely at the point of afterglow. The reverse was also true. Air velocity caused unusual behavior. It acted in two ways, to fan or intensify the burning by providing more oxygen or more rarely cause the samples to extinguish. Sometimes the air movement would nearly extinguish the burning, but the small amount of flame revived itself causing even greater afterflame and afterglow times than may have occurred otherwise. A difficulty arose when little bits of afterglow would drop to the bottom of the cabinet due to the air flow. In the still air at the bottom, they would burn considerably longer than if they had remained on the sample.

A last observation was that of the sample pulling out of the sample holder regardless of how tightly it was mounted. Because burning causes fabric shrinkage and fusion, the sample tears itself from the specimen holder. As a result, there is considerable controversy in the area of flammability testing as to whether rigid frames should be used or whether samples should be strung in a semi-restrained or unrestrained manner. The problem needs to be resolved for the effect on both afterflame and afterglow times appeared to be important. The causes of irregular burning revealed themselves to a great degree in the wide variability of burning times.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The major purpose of this study was to investigate the burning characteristics of multiple layer drapery fabric assemblies burning in varying air conditions. The investigation was undertaken as a supplement to Objective 2 of the Southern Regional Research Project S-86.

Multiple layer assemblies were burned so as to simulate as closely as possible actual drapery usage. Previous research had indicated a need for further study in the area of multiple layer drapery flammability incorporating air velocity. The flame resistance characteristics of two layer fabric assemblies with air spacing between layers, were tested. The assemblies were burned under both quiescent and ambient air conditions.

The basic test procedure followed was the American Association of Textile Chemists and Colorists standard test 34-1969 for the flammability of textile fabrics. The instrument used was a fire resistance tester specially designed by research personnel at the University of North Carolina at Greensboro to incorporate moving air into the testing chamber.

The fabric assemblies consisted of a two layer arrangement. The outer drapery layer had four possible fabrics each in two different weights. These consisted of a 100% cotton, a 100% linen, a 100% rayon, and a cotton/rayon blend. The second layer of the fabric assembly consisted of the lining layer. The two fabrics used for the lining layer were a 100% cotton and a 100% acetate fabric. The assemblies were burned with open spacing so that air could circulate between layers.

The laboratory data were collected by measuring afterflame time, afterglow time, and fabric damage of each sample. The data were analyzed based upon a 4 x 2 x 3 x 3 factorial design having 4 fabric types, 2 fabric weights, 3 linings, and 3 air velocity conditions. An analysis of variance was employed to determine the significance of each factor as well as their interactions. Fabric damage data was not analyzed statistically as originally planned because nearly all samples burned the entire length.

There was a significant difference in air velocity on both afterflame and afterglow times. An indirect relationship existed between the effect of air velocity on afterflame and afterglow times. Air velocity had a marked effect on the way fabrics burned as well as how long they burned. Moving air most often tended to fan the flames causing them to burn intensely. At times the velocity of the air was strong enough to extinguish the fire. Such long afterflame and afterglow times do not generally occur in still air conditions.

There was a significant difference in fabrics for both the afterflame and afterglow times for the four fabrics. Rayon had the lowest mean afterflame time and the cotton and rayon blend had the highest. The blend also had the highest mean afterglow time. Linen had the lowest mean afterglow time. Observation of actual burning showed that many of these cellulosic fabrics were tremendous fire hazards particularly in moving air conditions and with accompanying linings. There were tremendous flames and a great volume of smoke coming from many samples. Some of the products of combustion were undoubtedly toxic. Rayon and the cotton and rayon blends were the fabrics that appeared to be especially great fire hazards.

The two fabric weights differed significantly in both afterflame and afterglow. The heavy fabrics had a higher mean afterflame and afterglow time than the medium weight fabrics. Fabric weight appeared to be a very strong factor in influencing the burning characteristics. When weight was one of the factors, there was often a significant difference.

The most unexpected result of the study was related to the lining variable. It was significant only with air velocity for afterflame time. Afterflame times for all three lining conditions were within six seconds of each other. The range on the afterglow time with the three linings had more variability. The acetate fabric was the only one that melted, blistered, and dripped instead of charring. There were several instances of flaming drips reigniting fabrics.

The presence of lining did not affect burning times, yet did affect the way the sample burned considerably. The chimney effect was often produced wherein smoke and flames moved vertically between two fabric layers and streamed from the top of the sample. Even though both drapery and lining fabrics were ignited simultaneously, the lining often burned much more quickly.

Lining also seemed to be the cause for other burning irregularities such as sparking and unpredictable flame spread. It seemed that the addition of lining and air velocity caused unusual burning that was not always vertical as is seen to a great degree in the wide variability of burning times.

There was a significant interaction between Air Velocity and Fabric on both the afterflame and afterglow variables. The highest air velocity (3) resulted in high mean afterflame times for all fabrics and low mean afterglow times.

Air velocity produced a significant difference in afterflame and afterglow times with fabrics of two different weights. Afterflame time increased as air velocity increased. It showed that the difference in afterflame times of medium and heavy fabric in still air is much less than the difference between medium and heavy fabrics at Air Velocity 3. The opposite is true for afterglow.

There was a significant interaction between Air Velocity and Lining in the afterflame time, but not in afterglow time. This was the only instance when lining was a significant factor in the entire study.

The interaction of Fabric Type and Fabric Weight produced significant differences in afterflame and afterglow times. Heavier fabrics had higher afterflame and afterglow times than the medium weight fabrics with the exception of linen.

The interaction of Air Velocity x Fabric x Weight was the only three factor interaction that was significant. It was significant for both afterflame and afterglow times.

CONCLUSIONS

The conclusions made in this section are discussed in relation to the hypotheses presented in Chapter I.

Hypothesis 1. There is no significant difference in the burning characteristics (at the .01 significance level) of selected cellulosic drapery fabrics of heavy weight compared to fabrics of medium weight. This hypothesis was rejected based on the results of the statistically analyzed data. It may be concluded that afterflame and afterglow times are higher for heavier fabrics and lower for lighter fabrics.

Hypothesis 2. There is no significant difference in the burning characteristics (at the .01 significance level) of selected drapery fabrics when unlined rather than lined. This hypothesis was confirmed on the basis of statistically analyzed data.

Hypothesis 3. There is no significant difference between the unlined and lined fabric (at the .01 significance level) when exposed to varying air conditions. This hypothesis was rejected on the basis of afterflame data and accepted on the basis of afterglow data.

RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that further research in multiple layers be carried out. Areas of investigation might include the following:

1. Experiments should be carried out with drapery fabrics in rigid, semi-restrained, and unrestrained sample holders to determine the effect of the holder on the burning characteristics.

2. The effect air permeability has on each of the experimental fabrics in a multiple layer assembly should be investigated.

3. To more closely simulate usage research should be carried out on longer samples that have been double hemmed and pleated.

4. The flammability of coated drapery fabrics should be investigated duc to their wide spread usage.

5. Experiments with various types of fibers, constructions, and various finishes should be investigated.

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APPENDIX A

Analysis of Variance of Afterflame Data

SOURCE	DF	SS	MS	F
Air Velocity (AV)	2	329,527.01	164,763.51	275.78*
Fabric (F)	3	175,990.85	58,663.62	98.19*
Weight (W)	1	91,381.69	91,381.69	152.96*
Lining (L)	2	1,729.08	864.54	1.45
AV x F	6	62,601.17	10,433.53	17.46*
AV x W	2	15,578.27	7,789.13	13.04*
AV x L	4	8,852.08	2,213.02	4.00*
F x W	3	75,083.18	25,027.73	41.89*
F x L	6	3,731.88	621.98	1.04
W x L	2	1,138.62	569.31	0.95
AV x F x W	6	28,993.75	4,832.29	8.09*
AV x F x L	12	11,601.52	966.79	1.62
AV x W x L	4	6,804.91	1,701.23	2.85
F x W x L	6	9,553.64	1,592.27	2.66
AV x F x W x L	12	21,633.72	1,802.81	3.02
Error	216	129,046.26	597.44	
Total	287	973,247.65	339.11	

*Significant at the .01 level.

APPENDIX B

Analysis of Variance of Afterglow Data

SOURCE	DF	SS	MS	F
Air Velocity (AV)	2	1,206,612.61	603,306.30	152.28*
Fabric (F)	3	387,352.19	129,117.40	32.59*
Weight (W)	1	426,356.87	426,356.87	107.62*
Lining (L)	2	23,432.92	11,716.46	2.96
AV x F	6	192,835.34	32,139.22	8.11*
AV x W	2	214,931.91	107,465.96	27.13*
AV x L	4	20,796.54	5,199.13	1.31*
F x W	3	169,848.45	56,616.15	14.29*
F x L	6	6,078.91	1,013.15	0.25
W x L	2	981.52	490.76	0.12
AV x F x W	6	83,425.63	13,904.27	3.50*
AV x F x L	12	35,691.52	2,974.29	0.75
AV x W x L	4	4,692.32	1,173.08	0.30
F x W x L	6	23,904.58	3,990.10	1.01
AV x F x W x L	12	39,587.28	3,298.95	0.83
Error	216	855,731.39	3,961.71	
Total	287	3,692,295.98	12,865.14	

*Significant at the .01 level.