

PB88249958

Asbestos Substitute Fabrics for Safety Clothing

Grant Number 7 R01 OH 01431-01

Terminal Progress Report for  
the Period 09/28/79 through 12/31/82

Submitted to the  
Department of Health and Human Services  
National Institute for Occupational Safety and Health

by

Roger L. Barker

Principal Investigator

Department of Textile Materials and Management

North Carolina State University

Raleigh, North Carolina



REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No. PB88 24995815
4. Title and Subtitle Asbestos Substitute Fabrics for Safety Clothing		5. Report Date	
7. Author(s) Barker, R. L.		6.	
9. Performing Organization Name and Address North Carolina State University, Department of Textile Materials and Management, Raleigh, North Carolina, Terminal Progress Report		8. Performing Organization Rept. No.	
12. Sponsoring Organization Name and Address		10. Project/Task/Work Unit No.	
		11. Contract(C) or Grant(G) No. (C) (G) OH-01431-01	
		13. Type of Report & Period Covered	
15. Supplementary Notes		14.	
16. Abstract (Limit: 200 words) <p>Samples of over 70 different heat resistant fabrics were obtained and tested for flammability, thermal shrinkage, molten iron penetration and degradation. Other studies have sought to evaluate tensile strength, tearing strength, abrasion resistance, flexibility, air permeability, and thermal insulation value of the materials. A computer system was developed to handle the data generated from the studies. Information needed to define the performance criteria for such clothing was gathered through reviews of the literature, reports of industrial safety engineers, standards listed in ASTM Committee F23.80 on protective coverings, and from the manufacturers themselves. The thermal responses of the various fabrics were evaluated as to their ability to resist heat transfer and thermal disintegration on impact with molten iron, to their flammability on exposure to a vertical flame and by determining the minimum concentration of oxygen required to burn, and to their thermal shrinkage. Experiments were designed to measure the ability of the fabrics to withstand heat hazards encountered in the workplace. Experiments were also conducted to evaluate the textile properties of the fabrics including the fabric weight, thickness and density. The computer program as developed compares the asbestos/substitute fabrics systematically, based on the data obtained.</p>			
17. Document Analysis a. Descriptors			
b. Identifiers/Open-Ended Terms			
NIOSH-Publication, NIOSH-Grant, Grant-Number-OH-01431-01, Heat-resistant-materials, Flame-retardants, Protective-clothing, Safety-clothing, Work-clothing, Personal-protection, Ignitability			
c. COSATI Field/Group			
18. Availability Statement		19. Security Class (This Report)	21. No. of Pages
		20. Security Class (This Page)	11
			22. Price



## Summary of Progress

More than seventy different heat-resistant fabrics that might be used in industrial safety clothing or that might be considered asbestos substitutes in this application were identified. Sample fabrics were obtained from various commercial sources, and a systematic description and classification of these materials was made. A review was made of the testing and performance requirements for heat protective fabrics. A bibliography was published as a guide to research literature in this field (3). The contents of this literature were summarized and interpreted in light of the goals of this research. This research summary has been published in a technical journal (8).

The flammability and thermal shrinkage of a large number of potential asbestos substitute fabrics were evaluated and the results discussed in a technical paper (4). The resistance to penetration and degradation by molten iron were analyzed and correlated with the fiber type and fabric properties. These results were published in a scientific journal (1). Other findings were presented at a conference on fire safety (2).

A series of experiments have been conducted to determine the heat transfer by convection, resistance to open-flame, and the burn protection in these situations. Other experiments were conducted to predict burn protection. These tests used a specially designed Thermal Protective Performance (TPP) tester to measure heat transfer when the exposure is to a 50/50 combination of radiant to convective heat. Experiments were also conducted to measure the ability of the fabric to protect against burn injuries caused by direct contact with a hot surface. Some conclusions of these studies are described in a paper accepted for publication in a scientific journal (5). Other results were presented at a meeting of ASTM, F-23 on Protective Clothing (10).

Other experiments sought to evaluate the fabric tensile strength, tearing strength, abrasion resistance, bending flexibility, air permeability, and thermal insulation value. These findings have been useful in classifying the fabrics and in defining the need for modifications of standard test procedures.

Information has been accumulated on the performance requirements for heat-resistant fabrics used in industrial safety clothing. A computerized system has been developed to manage the laboratory data, to integrate end-use information, and to rank the fabrics in various categories on the basis of user preference. The technical aspects of this computerized system are described in a paper presented to a conference on textile physics and engineering (6) and in a paper presented at a conference on industrial fabrics (7). The results of the computer evaluation of the asbestos substitute fabrics are contained in a paper submitted for publication in a technical journal (9).

### List of Results

#### Identifying the Requirements for Heat-Resistant Fabrics in Industrial Safety Clothing

The following methods were used to obtain information needed to define performance criteria:

- (1) A review was made of the available literature: technical papers, trade journals, and reports of private and government studies on the needs and uses of high temperature fabrics. The contents of this literature were summarized and interpreted in light of the goals of this research.
- (2) Industrial safety engineers were surveyed to obtain information concerning the thermal and physical performance requirements for textile materials in an industrial environment. Contacts were established with safety professionals in various industries, including Reynolds Aluminum, Alcoa, General Motors, American Motors, Ford Motors, United States Steel, National Steel, and the Corning Glass Works.
- (3) Information on performance standards and materials specifications has been assimilated through active participation in the ASTM Committee F23.80 on Protective Clothing Materials for Exposure to Molten Substances.
- (4) Manufacturers of protective clothing were surveyed to determine the types of protective clothing manufactured, to obtain product specifications, and to determine the criteria for selecting textile materials.

The results of these surveys have been analyzed. The information obtained has been used to interpret the results of the laboratory tests made on the heat-resistant fabrics; and will influence the ultimate evaluation of the worth of these fabrics as materials for industrial protective clothing.

#### Identifying and Collecting Heat-Resistant Fabrics

The following methods were used to identify and classify the heat-resistant fabrics that are available and to obtain samples of these fabrics for testing and evaluation:

- (1) Heat-resistant fabrics that might be used in industrial safety apparel, or fabrics that might be considered asbestos substitutes in this application, were identified. These identifications were made

through personal meetings and discussions with safety engineers, makers of protective clothing and manufacturers who are currently producing, converting, or promoting fabrics for industrial protective apparel.

- (2) Samples of fabrics were obtained from various commercial sources having different heat-resistant fibers, blends of heat resistant fibers, fabric constructions, weights, weaves, refractive finishes, and multicomponent layers.
- (3) These fabrics were identified, classified, labeled, and made ready for testing and evaluation.

#### Evaluating the Thermal Response of the Fabrics

An important goal of this research is to evaluate the ability of various asbestos substitutes to protect against burn injuries resulting from hazards encountered in an industrial environment. Aspects of thermal protection were measured including flammability, linear shrinkage and heat degradation, resistance to hot and molten materials, and ability to withstand convective heat assault. During the reporting period, the following studies were conducted:

- (1) The ability of heat-resistant fabrics to resist heat transfer and thermal disintegration on impact with molten iron has been assessed. Maximum heat transferred through the fabrics was measured, and damage was evaluated in a controlled splash test. Ability to resist molten steel was correlated with fabric properties, including thickness and weight, air permeability, and the flammability characteristics. These tests represent an important industrial use of protective clothing against severe burn hazards.
- (2) Flammability was measured using two different methods of testing. The first method involved subjecting the fabrics to a vertical flame, and measuring the char length and the after-glow time. The second method used a specialized flammability tester to measure the minimum concentration of oxygen required to burn. These data provide useful quantitative assessments of the tendency of protective fabrics to ignite, a significant hazard for workers exposed to open flames, to sparks, or to the splashing of molten materials.
- (3) Thermal shrinkage and heat degradation was measured using a convection oven to expose test fabrics to temperatures of 300°C and 400°C for periods of 5, 10, and 15 minutes. These data provide an important basis for comparing protective values, since the potential

for skin burn injury is greatly increased by thermal shrinkage even if the fabric does not burn.

#### Experiments to Measure the Fire Athermacy of the Fabrics

Various designs of laboratory apparatus can be constructed, and different experimental approaches can be used to measure the ability of a fabric to resist the transfer of heat and to protect against burn injuries. An objective of this research was to assemble equipment and to choose experimental procedures with an emphasis on measuring the ability of the fabrics to withstand heat hazards encountered in the workplace. During the reporting period, the following steps were taken toward accomplishing this goal:

- (1) A review of the scientific literature was made to accumulate detailed information on the design and construction of test apparatus and test procedures.
- (2) Visits were made to laboratories and research centers, and communications were established with scientists knowledgeable in the testing of heat resistant fabrics including scientists at Dupont, Cotton Inc., Fabric Research Laboratories, Clemson University, Southern Research Institute, the Materials Laboratories of the Armed Services, and the National Bureau of Standards.

As a result of these efforts, the next objective was accomplished, which was:

- (3) to design and assemble apparatus, and to adapt experimental procedures to measure the transfer of convective heat and the resistance to an open-flame.

These methods were used to conduct the following study:

- (4) A manually operated shutter arrangement controlled exposure to a gas burner operated at  $2 \text{ cal/cm}^2/\text{sec}$ . An instrumented calorimeter located on the opposite side of the fabric measured the heat transferred. These data were converted to compute the protection index, estimated as timed protection against second degree burn injury. An analysis was made of the degradation and failure mode characteristic of each fiber type and fabric construction. The reviewer should see the paper, "Analysis of the Heat Transfer Characteristics of Fabrics in an Open Flame," for a detailed description of the experimental protocols used for this study.

Besides these simple flame exposures, the goal of this research called for the making of more sophisticated measurements to accurately simulate the type of

combined radiant and convective heat hazard encountered in the workplace. A commercial apparatus was acquired that incorporates sophisticated electronic and mechanical control devices. This device, called a Thermal Protective Performance (TPP) Tester, permits precise exposure to a combined radiant and convective heat source. The TPP tester was used to complete this phase of the project. In this regard:

- (5) Tests were conducted at  $2 \text{ cal/cm}^2/\text{sec}$  with the heat source set to generate a 50/50 combination of radiant to convective heat. Analyses of these data provided further insight into the fabric heat blocking capabilities, and the mechanisms of thermal degradation. They also indicate that burn protection is critically determined by the percentage mixture of the convective and radiant heat components. Fabrics that perform well when the radiant component is high (e.g. aluminized fabrics) afford significantly less protection when the heat source is mainly convective (open flames). These findings confirm the need for further study using a broader range of convective/radiant mixtures and heat intensity levels.

Experiments were also conducted to measure the ability of the fabric to protect against burn injuries caused by direct contact with a hot surface. These methods were used to conduct the following study:

- (6) A hot plate apparatus was used to measure the heat transferred through fabrics. Procedures were developed to determine a conductive protective value. The heat transferred was measured with the hot plate set to produce a  $2.0 \text{ cal/cm}^2/\text{sec}$  and a fabric sample contacting the hot surface at a pressure of  $0.5 \text{ lbs/in}^2$ . Limited testing showed that exposure to an intense conductive heat source produces comparisons among fabrics not predicted in radiant or convective transfer tests. Results of conductive testing are affected by the pressure of contact. They are also very sensitive to certain fabric properties, particularly the moisture content of the fiber. Further study is needed to scientifically explain these phenomena in terms of protection against chance exposures to highly heated surfaces.

#### Experiments to Evaluate the Textile Properties of the Fabrics

Many laboratory tests designed to measure properties that control the durability and comfort of protective fabrics were conducted during the reporting period. The following testing was completed:

- (1) Fabric weight, thickness, and density were measured using standard test methods. Additionally, lengthy test procedures were conducted to characterize aspects of the fabric structure and weave design

including threads per inch of fabric, cover factors, yarn size, yarn twist, and the amount of yarn crimp. Besides being useful in the interpretation of performance, these basic data are of immediate value in the engineering design of protective fabrics.

Tests were carried out to measure the durability including:

- (2) Tests of tensile strength and elongation and tests of the fabric's tearing resistance. Due to the high strength and the composite nature of many high performance textiles, standard tests had to be modified and special experimental procedures were developed to generate meaningful test results.
- (3) Using the Stoll Universal Wear Tester, the resistance to flexing and abrasion was measured by subjecting the sample to reciprocal folding and rubbing over a 1/16 inch thick bar under a tension of one-half pound. The number of cycles required to break the sample was recorded. Special experimental procedures were developed to generate meaningful test results.

Properties that determine comfort were measured, including:

- (4) Air Permeability determined following ASTM Standard Test Method D737-75.
- (5) Fabric stiffness, including bending length and flexural rigidity, determined using ASTM Standard Test Method D1388-64.
- (6) Fabric drapeability measured using a drapemeter technique to determine coefficients of fabric draping.

These data are useful in evaluating the comfort of protective fabrics. However, there is an additional need to measure properties related to heat stress, a significant performance factor in hot environments.

#### Defining Performance Criteria for Heat-Resistant Fabrics

A considerable amount of information has been accumulated concerning the requirements and uses of high-temperature fabrics in industrial safety clothing. Through continuing contacts with safety engineers, makers of protective clothing, and professional organizations a logical set of performance criteria is being defined, including performance requirements related to thermal protection, comfort and durability. Information was obtained on the demands placed on fabrics used to protect against molten steel or molten aluminum, significant hazards to workers in these industries. A systematic methodology was developed for predicting from laboratory

measurements the workplace performance of asbestos substitutes. This methodology was used to compare the fabrics tested by this research in various categories of performance.

#### Computer Aided Comparisons of Asbestos Substitute Fabrics

A sizeable volume of data was generated as a result of many physical and thermal tests made on more than 70 test fabrics. A computer was used to analyze these data, to organize information, generate graphs, and to do the statistical analysis that is required. In many cases, special programs were developed to interpret results, rank fabrics in performance categories, or to analyze the results of special test measurements. The computerized system that we developed to analyze our data base is unique. It has proven to be a powerful tool for making systematic comparisons among the asbestos substitute fabrics. A detailed description of the mathematical assumptions of the model has been presented at a conference in textile physics and engineering (6). The mechanics of the system and examples of how it is used to compare asbestos substitute fabrics were described at a conference on industrial fabrics and in a paper submitted for publication in a technical journal (7,9).

#### List of Publications

1. Barker, R. L. and M. Yener: "Evaluating the Resistance of Some Protective Fabrics to Molten Iron." Published in the Textile Research Journal, Vol. 51, pp 533-541, August 1981.
2. Barker, R. L. and M. Yener: "Protective Clothing: Evaluating the Performance of Some Asbestos Substitutes Against Molten Steel," a paper presented at the International Conference on Fire Safety, held in Menlo Park, California in January, 1981. Abstract published in the Proceedings of the International Conference of Fire Safety, Vol. 6, p. 190, January 1981.
3. Brewster, E. Pintauro and R. L. Barker: "Bibliography of Published Information on Heat Resistant Fabrics for Protective Clothing." Published in the Journal of Consumer Product Flammability, Vol. 9, pp. 11-19, March 1982.
4. Barker, R. L. and E. Pintauro Brewster: "Evaluating the Flammability and Thermal Shrinkage of Some Protective Fabrics." Published in the Journal of Industrial Fabrics, Vol. 1, pp. 7-17, Summer 1982.
5. Shalev, I. and R. L. Barker: "Analysis of the Heat Transfer Characteristics of Fabric in an Open Flame Exposure," accepted for publication in Textile Research Journal.
6. Kazmierczak, M., Shalev, I. and R. L. Barker: "Demonstrating a Computerized Model for Rating the Performance of Protective Fabrics," a

paper presented at the 1982 Textile Industries Conference, Orlando, FL, October 1982.

7. Kazmierczak, M., Shalev, I. and R. L. Barker: "Evaluating the New Heat Resistant Fabrics for Protective Clothing--A Systematic Approach," a paper presented at Industrial Fabrics Association International 70th Annual Conference, November, 1982, Las Vegas, Nevada (also published in the transactions of the Textile Technology Forum, IFAI).
8. Brewster, E., Pintauro and R. L. Barker: "A Summary of Research on Heat Resistant Fabrics for Safety Clothing." Published in the American Industrial Hygiene Association Journal, 44(2), pp. 123-130, February 1983.
9. Kazmierczak, M., Shalev, I. and R. L. Barker: "A Computerized Approach to Evaluating the Performance of Heat Resistant Protective Fabrics," a paper submitted for review and publication in the Journal of Industrial Fabrics.
10. Shalev, I. and R. L. Barker: "Demonstrating a Laboratory Method for Measuring the Thermal Protective Performance of Safety Fabrics in Flame Exposures," a paper presented to the ASTM Committee F23 on Protective Clothing, Atlanta, GA, January 1983.