AD ______________________

RDTE PROJECT NO. 1J664717DL4001

USATECOM PROJECT NO. 4-EI-485-AAC-008

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM

FINAL REPORT

BY

SP4 PHILIP G. DELDUKE
SCIENTIFIC AND ENGINEERING

NOVEMBER 1971

U S ARMY
GENERAL EQUIPMENT TEST ACTIVITY
FORT LEE, VIRGINIA

DISTRIBUTION LIMITED TO U.S. GOVERNMENT AGENCIES ONLY; TEST AND EVALUATION; NOVEMBER 1971. OTHER REQUESTS FOR THIS DOCUMENT MUST BE REFERRED TO COMMANDING GENERAL, U.S. ARMY NATICK LABORATORIES, NATICK, MASSACHUSETTS.

DEPARTMENT OF THE ARMY
HEADQUARTERS, U. S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005

AMSTE-BG

13 DEC 1971

SUBJECT: Suitability for Use of Lightweight Underwear of Winter Flight Clothing System, TECOM Project Nos. 4-EI-485-AAC-007/008

Commanding General
US Army Natick Laboratories
Natick, Massachusetts 01760

1. References.

a. RDTE Project No. 1J664717DL4001.

b. Letter, AMSTE-BG, TECOM, 8 July 1971, subject: Final Report of Service Test of Lightweight Underwear of Winter Flight Clothing System, USATECOM Project No. 4-EI-485-AAC-007.

c. Department of Army Approved Small Development Requirement for Clothing System for Army Aviation Crewmembers, 9 January 1966.

d. First indorsement, AMXRE-CCE, USANLABS, 24 March 1971, subject: Test Plan, Engineering Test of Lightweight Underwear of Winter Flight Clothing System, USATECOM Project No. 4-EI-485-AAC-008.

e. Letter, CDCMR-O, USACDC, 5 April 1971, subject: Plan for Service Test of Lightweight Underwear of Winter Flight Clothing System, USATECOM Project No. 4-EI-485-AAC-007 (USACDC ACNS: 7027 and 15873).

f. FONECON between CW3 Hanson, STEBG-TD-AC, and Mr. Conley, AMSTE-BG, 24 November 1971, subject: Electrostatic Characteristics of Standard Underwear (50 percent wool/50 percent cotton) Revealed During Service Test, TECOM Project No. 4-EI-485-AAC-007.

g. Letter, AMSTE-BG, TECOM, 11 March 1971, subject: Hazards of Static Electricity as it Relates to Electrically-Primed Aviation Munitions.

2. Approval Statement. The report of Service Test and the inclosed report of Engineering Test are approved except as stated herein. A copy of this letter should be attached to the report forwarded by reference 1b.

3. Background of Test.

a. The test item is a lightweight, two-piece, high-temperature-resistant-nylon underwear, designed primarily to provide increased crash fire protection to aircrewmen when used with the standard aviation uniform.

b. The US Army General Equipment Test Activity (USAGETA), Fort Lee, Virginia, conducted the engineering test utilizing 38 test items during the period January 1971 to October 1971. The US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, provided assistance to USAGETA.

c. The US Army Aviation Test Board conducted the service test utilizing 70 items (two items per aircrewman) during the period 10 January 1971 to 30 May 1971 at Fort Rucker, Alabama; Apalachicola, Florida; Manitoba and Ontario, Canada; and Fort Greely, Alaska.

d. In addition to evaluating the experimental underwear against appropriate criteria of reference 1c, the engineering and service tests included comparative evaluations with the Army standard-issue underwear. The standard underwear is of identical design to the experimental underwear except for the basic fabric which consists of 50 percent cotton and 50 percent wool.

e. The engineering test plan was coordinated with the US Army Natick Laboratories (USANLABS), reference 1d. The service test plan was approved by the US Army Combat Developments Command, reference 1e.

4. Test Results.

a. Criteria Met. Both the experimental and standard-issue underwear met the eight requirements used as test criteria for the service test. Of the 14 requirements used as criteria for the engineering test:

(1) Nine requirements were met by both the experimental and standard underwear.

(2) Both the experimental and the standard underwear failed to meet three requirements (Items 10, 12, and 14, Appendix II, Engineering Test Report and paragraph 4.c.(1) below).

(3) One requirement was met by the standard underwear but was not met by the experimental underwear (item 7, Appendix II, Engineering Test Report).

(4) One requirement was not met by the experimental underwear and was not determined for the standard underwear (item 6, Appendix II, Engineering Test Report).

Three deficiencies and one shortcoming were reported against the experimental underwear during the engineering test, and one deficiency was reported against the experimental underwear during the service test, which did not address a listed requirement. After analysis, consolidation, and reclassification by this headquarters, one deficiency and two shortcomings result. The deficiency also applies to the standard underwear but to a lesser degree.

b. Deficiency (1). The experimental underwear, when worn as an undergarment to the standard nomex flight uniform, failed to meet the uniform system thermal protection criterion, i.e., provide burn protection from high intensity fire for ten seconds. The standard underwear/nomex uniform combination, although not meeting the criterion, provided equal or better protection under the test conditions than the experimental underwear/nomex uniform combination.

c. Shortcomings (2).

(1) The electrostatic characteristics of both the experimental and standard underwear were unsatisfactory. Both types of underwear failed to meet the accumulated charge criterion (500 volts maximum allowable) and both types of underwear caused discomfort to users when accumulated charges were discharged, reference 1f. The experimental underwear also failed to meet the criterion for surface resistivity (met by standard underwear). Although not identified as such in the test reports, this condition is regarded as a possible critical safety hazard of undetermined degree when handling rockets and electrically-sensitive munitions. The test results relating to electrostatic characteristics were reported as two deficiencies by the engineering test agency and one deficiency by the service test agency. These deficiencies are consolidated and reclassified as a shortcoming because there is no known correlation between the test results and the existance of a safety hazard nor is the aircrewman's performance significantly degraded in the accomplishment of his tasks.

(2) The melting/decomposition temperatures for the sewing yarn, elastic tape, and labels of the experimental underwear were less than that of the basic body fabric. Although this is generally undesirable, the degree of difference when considered in conjunction with the lowest temperature at which decomposition occurs (approximately 700°F) results in only a minor degradation of protection.

d. Safety. See paragraph 4.c.(1).

e. Maintenance/Maintainability. No maintenance/maintainability problems were encountered with either the experimental or standard underwear.

f. Durability. There were no quantitative criteria for durability. Of the limited qualitative durability criteria, all were met by both the experimental and standard underwear.

5. Comments.

a. Results from the thermal protection tests show that aircrewmen will be protected from first degree burns for only a very short period of time (less than two seconds versus the ten second requirement) when exposed to a well-developed JP-4 fire and while wearing either the nomex underwear or standard underwear as an undergarment to the standard nomex uniform. It is emphasized that test results reflect the most severe conditions that can be expected in post crash fire environment, i.e., very near the highest possible heat flux and a tight-fitting clothing system. In real crash fire situations, aircrewmen can expect greater time periods of burn protection since the average heat flux exposure will be less than the test condition of 14 Btu/ft^2/sec and the majority of the body will be clothed with loose-fitting rather than tight-fitting garments.

b. Per reference 1g, this headquarters asked the US Army Munitions Command (MUCOM) for criteria to be used in evaluating the degree of hazard associated with the electrostatic charge build-up on aviation clothing. Although MUCOM provided some excellent background information on static electricity problems, the information was not useable as criteria for this test. As an interim measure, this command established as a safety criterion that the electrostatic charge build-up shall not exceed 500 volts at 0°F. This is an interim criterion and requires verification.

AMSTE-BG 13 DEC 1971

SUBJECT: Suitability for Use of Lightweight Underwear of Winter Flight Clothing System, TECOM Project Nos. 4-EI-485-AAC-007/008

6. Conclusions. The experimental nomex underwear is unsuitable for Army use.

7. Recommendations.

a. New fabrics and/or clothing systems be developed which will meet the ten-second burn protection criterion of reference 1c.

b. Definitive criteria be established for use in evaluating the degree of hazard associated with the build-up of electrostatic charge on aviation clothing with particular reference to electrically-sensitive munitions.

FOR THE COMMANDER:

Henry F. Grimm, Jr.

HENRY F. GRIMM, JR.
Colonel, GS
DCS for Test and Evaluation

1 Incl
as (1 cy)
USAGETA Report, TECOM Project No. 4-EI-485-AAC-008

Cy Furn:
CG AMC, AMCRD-JI (3 cys)
CG USACDC, USACDC LnO, TECOM (23 cys)
CG USANLABS, AMXRE-CCE (4 cys)
CG USCONARC, ATIT-RD-MD (6 cys)
CO USALDSRA, LDSRA-ME (1 cy)
CO USAGETA, STEGE-AO (w/o incl)
Pres USAAVNTBD, STEBG-MO (w/o incl)

RDTE PROJECT NO. 1J664717DL4001

USATECOM PROJECT NO. 4-EI-485-AAC-008

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM

TEST REPORT

BY

SP4 PHILIP G. DELDUKE
SCIENTIFIC AND ENGINEERING

NOVEMBER 1971

U.S. ARMY
GENERAL EQUIPMENT TEST ACTIVITY
FORT LEE, VIRGINIA

U.S. ARMY EQUIPMENT TEST ACTIVITY
FORT LEE, VIRGINIA

USATECOM 4-EI-485-AAC-008

Final Report of Engineering Test of Winter Flight Clothing System

November 1971

ABSTRACT

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USAGETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded that test item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

It is recommended that the deficiencies and shortcoming be corrected, and that criteria for electrostatic characteristics be re-evaluated.

FOREWORD

The U.S. Army General Equipment Test Activity was responsible for planning and conducting the test and preparing the Final Report for the Engineering Test of the Lightweight Underwear of the Winter Flight Clothing System. However, the U.S. Army Aeromedical Research Laboratory at Fort Rucker, Alabama, conducted the thermal protection phase of the Engineering Test.

TABLE OF CONTENTS

SECTION 1. SUMMARY

1.1 BACKGROUND

a. A Department of the Army approved requirement, for both a summer and winter aviation crewman's uniform, was established in 1966. A candidate high temperature resistant nylon (HTRN) summer uniform was tested by USATECOM in 1968 resulting in the Department of the Army adopting this summer uniform, after some modification, as Standard A.

b. Pilot and crew compartments of U. S. Army aircraft can be maintained at a minimum of +40° F. by integral heaters. This has led to a Department of the Army decision that a winter aviation crewman's uniform will not specifically be developed, but that the adopted uniform will be supplemented during cold weather by the following items:

HTRN underwear (subject test item)

Intermediate jacket (under development)

Heavy jacket (under development)

c. Additional cold environmental protection will be afforded flight crewmen when involved in ground activities by adding, externally, any necessary standard U. S. Army cold weather garments.

d. Test plans were prepared for engineering test at U. S. Army General Equipment Test Activity and service test at the U. S. Army Aviation Test Board. Based on early findings in respect to a potential safety hazard due to buildup of static electricity in the material, the test plan was amended to include a subtest for determining electrostatic characteristics.

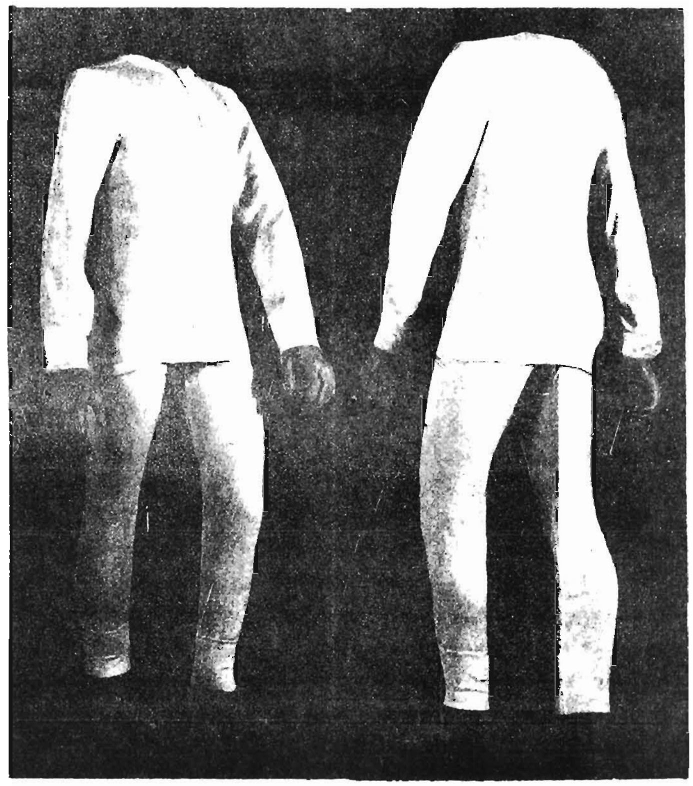
1.2 DESCRIPTION OF MATERIEL

The test item was a two-piece, lightweight, HTRN underwear, designed as an undergarment in the winter flight clothing system (Fig. 1). The undershirt and drawers were rib knit, similar in construction to the current standard 50-percent cotton/50-percent wool items. The test underwear was furnished in five sizes: extra small, small, medium, large, and extra large.

1.3 TEST OBJECTIVE

The overall objective of this engineering test was to determine the technical characteristics of the HTRN underwear and the standard-issue underwear, and make a comparative evaluation.

STANDARD



EXPERIMENTAL

Figure 1. Standard and Experimental Lightweight Underwear of Winter Flight Clothing System.

1.4 SCOPE

a. The Engineering Test (ET) of the HTRN underwear was conducted at the U. S. Army General Equipment Test Activity, (USAGETA), Fort Lee, Virginia, from January to October 1971. Concurrently, the thermal protection testing phase of ET was conducted at the U. S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, in March 1971.

b. The engineering test included specific evaluations of the garment sizing, shrinkage, and capability of providing environmental confort. Additionally, the characteristics of flammability, thermal protection, and electrostatic dissipation were tested on quantities of the underwear fabric when new and after 20 launderings. The testing techniques were both destructive and nondestructive, employing Federal Test Method Standards as well as locally developed procedures. In instances of comparative testing, the standard underwear is defined: Undershirt, Man's, Full Sleeve and Drawers, Men's, Ankle Length, both garments 50-percent cotton, 50-percent wool knit, type classified Standard A in 1966, and procured under specifications listed as References 6 and 7, Appendix V.

c. All experiemental and standard underwear garments were code-marked and visually inspected for defects. At least 50 percent of all sizes of experimental underwear were measured to verify size. Three sets of experimental underwear were laundered 20 times to determine shrinkage.

d. Five specimens of experimental and standard underwear fabric were evaluated for flammability and electrostatic properties and applied to new and laundered fabrics. The electrostatic characteristics were initially investigated by surface resistivity measurements (par. 2.3.3c). Subsequently, NLABS provided additional samples of experimental underwear, which were specially treated to reduce electrostatic charge. Using these additional samples, the more controlled subtest for Electrostatic Characteristics (Par 2.8) was conducted on all three clothing systems (standard, original experimental, and the treated experimental). Duplicate differential thermal analysis (DTA) was performed on all experimental garment components to detect non-HTRN fibers, if present, by decomposition or melting temperatures.

e. Twelve participants provided subjective comfort data during environmental protection testing.

f. Thermal protection testing was conducted at USAARL on 18 unconscious live animals. Six fabric protecting systems were tested once on each of six animals at 1.75-second exposure to flame. A second group of six animals was tested similarly at a 3.5-second exposure, and a third group of six animals at a 7.0-second time interval.

g. Value analysis and safety were evaluated throughout testing.

h. All statistical evaluations of basic data were made at the 95-percent confidence level. The sample size was considered adequate for testing.

i. Electrostatic charges accumulated on nine participants were measured at 40°F., 20 percent relative himidity (RH) in a flight clothing system, and at 0°F. in flight clothing complemented by cold-dry protective clothing.

1.5 SUMMARY OF RESULTS

a. Twenty-five sets of experimental, 25 sets of standard, and 13 sets of antistatic treated experimental underwear were received. All items were coded and inspected. No material defects were found (Par. 2.1.4).

b. Standard and experimental garment sets were measured and weighed (App. I-A). Criteria were satisfactorily met (Par. 2.2.5).

c. Experimental items satisfactorily met flame time, char length, and glow time requirements (Par. 2.3.5a).

d. Some components of the experimental underwear deviated in thermal degradation properties from the body fabric, a shortcoming (Par 2.3.5b).

e. The original untreated experimental underwear exceeded surface resistivity criteria (Par 2.3.5c). The new antistatic treated items showed no improvement in surface resistivity (Par 2.8.5).

f. All test items satisfactorily passed shrinkage requirements (Par 2.3.5d).

g. All test items provided wearer comfort exceeding 3 hours (Par. 2.4.5).

h. The following results for the thermal protection subtest are included in USAARL Report No. 71-19, Appendix I-E (Par. 2.5.5).

(1) None of the fabric systems evaluated met the essential requirements for thermal protection for aviator flight clothing, a deficiency.

(2) Single layer fabric systems offered slight protection.

(3) Double-layered systems evaluated offered more than three times the protection of single layer systems, but still fall below the criteria.

(4) Standard underwear worn under an HTRN uniform provided equal or better protection than experimental underwear under the HTRN uniform.

(5) Washing did not affect thermal protection.

i. No costly, nice-to-have features were noted in the experimental underwear (Par 2.6.4).

j. No unsafe features were noted in the experimental underwear (Par. 2.7.4).

k. Results for electrostatic characteristics showed that all three clothing systems significantly exceeded the criteria when the flight jacket was removed, a deficiency (Par 2.8.5).

1.6 CONCLUSIONS

a. The experimental underwear met the technical performance requirements except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges.

b. There was no significant difference between performance of the experimental versus the standard items.

1.7 RECOMMENDATIONS

It is recommended that:

a. The deficiencies and shortcoming (App. III) be corrected.

b. The criteria for electrostatic characteristics (500-volt maximum) be re-rvaluated for validity in light of the results (Par 2.8.4 and App. I-D).

SECTION 2. DETAILS OF TEST

2.1 IDENTIFICATION AND INSPECTION

2.1.1 Objectives

a. To identify each experimental and standard underwear item to be tested.

b. To inspect each experimental and standard underwear for material, workmanship, or functional defects.

2.1.2 Criteria

a. Each experimental and standard underwear item will be indelibly marked for test control (Item 1, App. II).

b. Each experimental and standard underwear item entering subsequent testing must be free from apparent material, manufacturing, or functional defects (Item 2, App. II).

2.1.3 Method

a. Underwear items were segregated by type (experimental and standard), by garment (undershirt and drawers), and by size (extra large, large, medium, small, and extra small). A count was made for verification and accountability. Sets of underwear were established by combining a pair of drawers and an undershirt of the same type and size. Both garments were indelibly coded with the same identification marking.

b. All garments of the experimental and standard underwear sets were visually inspected for fabric, seam, and other construction defects. Bolt fabrics were also received and inspected.

2.1.4 Results

a. Twenty-five sets of experimental underwear, distributed throughout five sizes, were received for testing. Their distribution by size and assigned indelible code number is shown below:

Set Code Number	Size
1, 2	Extra Small (X-S)
3 through 14	Small (S)
15 through 21	Medium (M)
22, 23	Large (L)
24, 25	Extra Large (X-L)

Each experimental garment was labeled at 100-percent nylon. Twenty-five sets of standard underwear were received and were distributed by size and assigned indelible code numbers identically as shown above. Midway through testing, a second type (13 sets) of experimental underwear was received. These thirteen sets differed from the original experimental underwear in that the developer had applied an anti-electrostatic finish. To provide proper size distribution to these treated garments, USAGETA applied the anti-electrostatic finish (as directed in Reference 6, Appendix V) to five sets of size small experimental underwear. These sets were also coded. The set code numbers and sizes of treated experimental underwear follow:

Set Code Numbers	Size
26, 27	Extra Small (X-S)
3, 5, 7, 8, 9	Small (S)
28 through 34	Medium (M)
35, 36	Large (L)
37, 38	Extra Large (X-L)

b. The following bolt fabrics were received and inspected:

20 yds	experimental underwear (untreated)
20 yds	standard underwear
10 yds	Aviator's uniform, HTRN

All garments and fabrics were found free from material, workmanship, of functional defects.

2.1.5 Analysis

All test items were properly inspected, identified, marked, and cleared for initiation of testing.

2.2 PHYSICAL CHARACTERISTICS

2.2.1 Objective

To determine the weight and essential dimensions, by size, of both experimental and standard underwear garments.

2.2.2 Criteria

a. The experimental undershirts must meet the weight and finished measurements established for the standard undershirts in Table V, MIL-U-43262A (Item 3, App. II).

b. The experimental drawers must meet the weight and finished measurements established for the standard drawers in Table VI, MIL-D-43261A (Item 4, App. II).

2.2.3 Method

Both standard and experimental underwear garment sets were measured, to the nearest 1/16 inch in the six locations described on the garment diagram in Appendix I-A, and weighed to the nearest 0.01 pound. The sampling, in percent of garments measured in this test by size, is as follows:

Size	Sampling, Percent
Extra Small (X-S)	100
Small (S)	50
Medium (M)	50
Large (L)	100
Extra Large (X-L)	100

Individual garments of the same sampling were weighed to the nearest 0.01 pound.

2.2.4 Results

A summary of average garment dimensions and weights is shown in Appendix I-A.

2.2.5 Analysis

a. Appendix I-A shows the experimental underwear being out of standard specifications only in the body width measurement of sizes X-small, medium, and X-large. These measurements, although all greater than the maximum specification limit, are not more than 4-percent excessive. Such a small deviation in the width of a knit undershirt is of no practical consequence. The experimental underwear met the specification requirement for the current standard underwear.

b. The only X-large size standard underwear available for issue for this test was Standard B. Although these sets were also 50 percent cotton/50 percent wool, the basic higher fabric weight is noticeable in Appendix I-A. The garment labels indicated M-1950 models and the following two outdated stock numbers: SS-U-7054 and SS-D-514. These two sets of X-large standard underwear were not used in any subsequent testing and their presence in this subtest is of no importance.

2.3 MATERIAL PROPERTIES

2.3.1 Objectives

a. To determine the flammability characteristics of the experimental and standard underwear fabrics as influenced by laundering.

b. To determine the thermal degradation character of the following components of the experimental underwear: body fabric, sewing threads and yarns, cuff fabrics, and tapes.

c. To determine the electrostatic characteristics of the experimental fabric as influenced by laundering.

d. To determine the shrinkage of experimental underwear and fabric throughout laundering.

2.3.2 Criteria

a. TC Statement to SDR Par. 2b(2): "The clothing for Army Aviation Crewmembers will be made of a material which will be flame resistant (i. e., when subjected to contact with flame, not continue to burn when the flame source is removed). This requirement is determined by Method 5903 of CCC-T-191 in which the after-flame and char length requirements measures the tendency of the materiel to flame after removal of a flame source" (CCC-T-191 is now superseded by FTMS 191) (Item 5, App. II).

b. No fabric or fiber components of the experimental underwear will exhibit lower thermal degradation properties than the basic body fabric (Item 6, App. II).

c. The surface resistivity of new and laundered experimental underwear body fabric will not be greater than 3.2×10^{12} ohms per square unit. (Resistivities exceeding 3.2×10^{12} are industrially classified as Poor to Unsatisfactory) (Item 7, App. II).

d. The experimental underwear shall not shrink more than 8.0 percent throughout 20 launderings (Item 8, App. II).

2.3.3 Method

a. Four fixed laundering operations were necessary to prepare the fabric and garments for later testing. Each fixed laundering operation was performed 20 times to produce laundered items and is described below:

Items Laundered	TM 10-354, Appendix III	Dryer Exhaust Temp
Experimental underwear	Formula B, less Operations	180 to 200° F.
Standard underwear	Formula G	130° F. maximum
HTRN uniform fabric	Formula E	180 to 200° F.

Flammability characteristics of the following fabrics were determined by Method 5903 of FTMS 191, December 1968:

Fabric	Condition	No. of Specimens Wale Direction Only
Experimental underwear	New	5
	Laundered 20 times	5
Standard	New	5
	Laundered 20 times	5

b. Differential thermal analysis (DTA) techniques were used to determine the decomposition or melting temperatures of components of the unlaundered experimental underwear. Thermograms were produced on a DuPont Model 900 Differential Thermal Analyzer, scanning at a rate of 20° C. per minute from ambient to 500° C. in an intermediate cell with air blanket. Each of the following garment components were tested in duplicate:

Body fabric	Tape
Cuff fabric	Jean Cloth
Sewing yarn	Elastic webbing
Labels, if any	

c. Surface resistivity measurements, one indicator of electrostatic character of fabrics, were determined by AATCC Method 76-1964 employing Keithley Modules 6105, 610B, and 240 at 100 VDC. Each of the following fabrics were tested at 70° F., 25-percent RH; 70°F., 65-percent RH; and 70° F., 95-percent RH:

Fabric	Condition	No of Specimens
Experimental underwear	New	5
	Laundered 20 times	5
Standard	New	5
	Laundered 20 times	5

d. Three sets of experimental underwear were dimensionally measured in four locations (App. I-A measurements, A, B, D, E) and recorded. Six panels of experimental underwear fabric were marked with 10 x 10-inch squares following wale and course directions. These three sets of underwear and six fabric panels were entered in the repetitious laundering described in paragraph 2.3.3a. All measurements were again recorded for each test item at the conclusion of the following number of launderings: 2, 5, 10, and 20.

2.3.4 Results

a. Flame time, glow time, and char length results are recorded in Table I, Appendix I-B.

b. Thermal decomposition values determined by DTA are included in Table II, Appendix I-B.

c. Surface resistivity values are found in Table III, Appendix I-B.

d. Average percent change for the six 10-x 10-inch panels are shown graphically in Figure 1 (Table), Appendix I-B. Percent change in measurements specified in Table VI, MIL-D-43261A, are graphically presented in Figure 2 and (Table), Appendix I-B.

2.3.5 Analysis

a. Flame time values (Table I, App. I-B) for experimental underwear exceeds the criterion by 0.52 second for an unlaundered item and 1.3 seconds after the 20th laundering of the item. This difference, however, is deemed to be within acceptable limits. There is no significant difference in flame time and char length between new and laundered experimental underwear. The difference in glow times between new and laundered experimental underwear shows significance, but in the direction of a reduction with laundering.

b. DTA results (Table II, App. I-B) show the following components to be less than the criteria:

Sewing yarns (Shirt and Pants)
Labels (Shirt and Pants)
Tape (Shirt and Pants)
Elastic (Pants)

c. Table III, Appendix I-B, shows that all surface resistivities of experimental underwear and the unlaundered standard item at 70° F and 25 percent RH exceed the criteria, under all three conditions of temperature and relative humidity, a deficiency (App. III, Item 1.1). In addition, laundering significantly increases the surface resistivity at all conditions.

d. With the exception of the measurement of the drawer waistband (F), Figure 1, Appendix I-B, indicates no fabric measurement exceeding the 8.0-percent maximum shrinkage requirement. This amount of shrinkage is considered to be of no practical significance in the elastic waistband.

2.4 ENVIRONMENTAL COMFORT

2.4.1 Objective

To determine the mean duration of personnel comfort, provided by the experimental and standard underwear when worn under standard outergarments, in an environment of 40°F.

2.4.2 Criterion

SDR Par. 2c(1) (ESSENTIAL) The winter clothing system should protect the wearer and be designed for use under the climatic criteria contained in AR 70-38, with the exception that the cold weather protection of the basic uniform will be that which will be required in a 40°F. cockpit temperature environment. Supplementary clothing protection shall be available for cold weather Categories 6, 7, and 8 as defined in AR 70-38. (Item 9, App. II).

2.4.3 Method

a. The two clothing systems first compared in this test were:

Standard System No. 1 (Std-1)

Summer Underwear
Winter Underwear
Aviator's Uniform
Wool Socks
Leather Combat
Aviator's Helmet, SPH4
Aviator's Gloves

Experimental System No. 1 (Exp-1)

Summer Underwear
Experimental Underwear
Aviator's Uniform
Wool Socks
Leather Combat Boots
Aviator's Helmet, SPH4
Aviator's Gloves

(All clothing items were current U.S. Army Standard A except that underscored.)

b. The two clothing systems next compared in this test were:

Standard System No. 2 (Std-2)

Same as Std-1, plus:

Jacket, Aviator's, Intermediate Weight

Experimental System No. 2 (Exp-2)

Same as Exp-1, plus:

Jacket, Aviator's, Intermediate Weight

c. Twelve participants in this test were divided into 3 groups of 4 men each. One group at a time was exposed to the single testing condition of 40$\pm$ 2°F., 80 to 90 percent RH, in the USAGETA Climatic Test Chamber for 3 hours at a low activity level. Two of the four men wore a standard clothing system, the other two wore an equivalent experimental clothing system. Table I sets forth the wear schedule by participant number.

TABLE I

ENVIRONMENTAL COMFORT TEST SCHEDULE

Participant		Clothing System Worn by Test Day							
		FIRST		SECOND		THIRD		FOURTH	
Group	Number	AM	PM	AM	PM	AM	PM	AM	PM
1	1	Std-1	Exp-1	Std-2	Exp-2	Exp-1	Std-1	Exp-2	Std-2
	2	Exp-1	Std-1	Exp-2	Std-2	Std-1	Exp-1	Std-2	Exp-2
	3	Std-1	Exp-1	Std-2	Exp-2	Exp-1	Std-1	Exp-2	Std-2
	4	Exp-1	Std-1	Exp-2	Std-2	Std-1	Exp-1	Std-2	Exp-2
2		FIFTH		SIXTH		SEVENTH		EIGHTH	
		AM	PM	AM	PM	AM	PM	AM	PM
	5	Exp-1	Std-1	Exp-2	Std-2	Std-1	Exp-1	Std-2	Exp-2
	6	Std-1	Exp-1	Std-2	Exp-2	Exp-1	Std-1	Exp-2	Std-2
	7	Exp-1	Std-1	Exp-2	Std-2	Std-1	Exp-1	Std-2	Exp-2
	8	Std-1	Exp-1	Std-2	Exp-2	Exp-1	Std-1	Exp-2	Std-2
3		NINTH		TENTH		ELEVENTH		TWELVETH	
		AM	PM	AM	PM	AM	PM	AM	PM
	9	Std-1	Exp-1	Exp-2	Std-2	Exp-1	Std-1	Std-2	Exp-2
	10	Std-1	Exp-1	Exp-2	Std-2	Exp-1	Std-1	Std-2	Exp-2
	11	Exp-1	Std-1	Std-2	Exp-2	Std-1	Exp-1	Exp-2	Std-2
	12	Exp-1	Std-1	Std-2	Exp-2	Std-1	Exp-1	Exp-2	Std-2

d. The test participants were measured, fitted, and properly dressed in the scheduled clothing systems. One group of four men entered the controlled chamber and were seated. Every 15-minute interval thereafter, throughout the 3-hour exposure, each participant was privately interviewed by telephone for comfort. His coded responses were recorded on data sheets and represented the rating of the first clothing system. At the conclusion of his test day, each participant also ranked the two clothing systems worn that day and offered supporting comments. This procedure was repeated until each of the 12 participants had been twice exposed to all four clothing systems.

2.4.4 Results

The results are shown graphically in Appendix I-C.

2.4.5 Analysis

Each of the four clothing systems provides the wearer comfort exceeding 3 hours. No apparent difference is detectable between the standard and the experimental underwear within a clothing system. The addition of the intermediate jacket provides greater comfort in both systems.

2.5 THERMAL PROTECTION

2.5.1 Objective

To determine the extent of skin and tissue damage, produced on test animals exposed to severe fire conditions, when clothed by both experimental and standard underwear fabric under the standard HTRN uniform fabric.

2.5.2 Criterion

SDR Par. 2b(2) "Features which are essential to all components of these uniforms are: (ESSENTIAL) All components must be fire-retardant to a degree which will provide for protection from high intensity flash or flame for 10 seconds duration. This degree of protection must last for the life of the garment" (Item 10, App. II).

2.5.3 Method

See USAARL Report No. 71-19, Appendix I-E.

2.5.4 Results

See USAARL Report No. 71-19, Appendix I-E.

2.5.5 Analysis

(a) None of the fabric systems evaluated meet the essential requirements for aviator flight clothing.

(b) Single layer fabric systems offer slight protection.

(c) Double-layered systems offer more than three times the protection of the single layer systems, but still fall below the criteria.

(d) Standard underwear worn under an HTRN uniform provides equal or better protection than experimental underwear under the HTRN uniform.

(e) Washing does not affect thermal protection.

2.6 VALUE ANALYSIS

2.6.1 Objectives

To determine if the experimental underwear has any unnecessary, costly, or nice-to-have features which may be eliminated without adversely affecting the essential performance requirements, quality, or safety (USATECOM Reg 700-1).

2.6.2 Criterion

The experimental items will have no unnecessary, costly or nice-to-have features (Item 11, App. II).

2.6.3 Method

All experimental garments were initially inspected under the critical view for necessity of all features. As subsequent testing evolved, project personnel were continuously alert for indicators of any unnecessary, costly, or non-essential features.

2.6.4 Results

No costly or nice-to-have features were noted in the experimental items.

2.6.5 Analysis

None

2.7 SAFETY

2.7.1 Objectives

a. To determine if any user safety hazard exists in the design or construction of the experimental underwear.

b. To insure all testing and related activities are conducted in a manner which meets applicable safety requirements and protects personnel and equipment.

2.7.2 Criteria

a. The experimental underwear will impose no unusual hazard to the wearer (Item 12, App. II).

b. All personnel, whose activity relates to this testing, will be adequately indoctrinated and supervised in safety practices (Item 13, App. II).

2.7.3 Method

Paragraph 7 of the Test Directive (Ref. 1, App. V) indicated there was no known safety hazard associated with wearing the experimental underwear. A continuous safety surveillance was maintained by project personnel throughout testing with the specific intent of detecting and defining material, design, function, or other characteristics of the experimental underwear which were or could be hazardous to the wearer. Adequate firefighting and protective safeguards, to shield personnel and equipment involved in flame testing, were on hand or designed into the test apparatus. Positive, on-the-spot action was taken to eliminate unsafe acts and conditions of test.

2.7.4 Results

No unsafe features were noted in the experimental items.

2.7.5 Analysis

The experimental items are satisfactory from a safety standpoint.

2.8 ELECTROSTATIC CHARACTERISTICS

2.8.1 Objective

To determine the electrostatic charges accumulated on test personnel when wearing experimental and standard underwear in combination with appropriate clothing in controlled environments.

2.8.2 Criterion

The electrostatic charge, accumulated on test personnel wearing experimental underwear in combination with appropriate additive environmental clothing, will not exceed 500 volts at 0°F. (Item 14, App. II). (The criterion for this subtest is considered to be interim in nature, and is subject to verification—Ref 12 through 16, App. V).

2.8.3 Method

a. The three clothing systems compared in this test at 40±3°F, 30±3 percent RH, were:

Standard System No. 3 (Std-3)

Summer Underwear
Winter Underwear
Aviator's HTRN Uniform
Aviator's Jacket, MA-1
Wool Socks
Leather Combat Boots
Insulating Cap
Aviator's HTRN Gloves

Experimental System No. 3A (Exp-3A)

Summer Underwear
Untreated Experimental Underwear
Aviator's HTRN Uniform
Aviator's Jacket, MA-1
Wool Socks
Leather Combat Boots
Insulating Cap
Aviator's HTRN Gloves

Experimental System No. 3B (Exp-3B)

Same as Exp-3A above except electrostatic treated experimental underwear was substituted for the untreated (Par. 1.4d)

NOTE: All clothing items were current U. S. Army Standard A except those underscored.

b. The three clothing systems compared at 0°F, low humidity were:

Standard System No. 4 (Std-4)

Summer Underwear
Winter Underwear
Aviator's HTRN Uniform
Field Jacket w/Liner
Field Trousers w/Liner
Insulating Cap
Aviator's HTRN Gloves
Arctic Trousers w/Liner
Parka w/Liner and Fur Hood
Wool Socks
White Insulating Boots
Arctic Mitten Set

Experimental System No. 4A (Exp-4A)

Summer Underwear
Untreated Experimental Underwear
Aviator's HTRN Uniform
Field Jacket w/Liner
Field Trousers w/Liner
Insulating Cap
Aviator's HTRN Gloves
Arctic Trousers w/Liner
Parka w/liner and Fur Hood
Wool Socks
White Insulating Boots
Arctic Mitten Set

Experimental System No. 4B (Exp-4B)

Same as Exp-4A above except electrostatic treated experimental underwear was substituted for the untreated.

c. Nine enlisted personnel were participants in this test and were divided into 3 groups of 3 men each. Each man was measured and fitted with the scheduled clothing systems. One group was exposed to a 40° F, 30 percent RH chamber condition for up to 1 hour at a low activity level. During this acclimation period, each of the three clothing systems, described in paragraph 2.8.3a, was worn and subsequently tested. Table II sets forth the clothing system wear schedule by participant number.

TABLE II

ELECTROSTATIC TEST WEAR SCHEDULE

CHAMBER CONDITIONS	PARTICIPANT NUMBERS			CLOTHING SYSTEM WORN BY TEST DAY FIRST	SECOND	THIRD
40°F	1	4	7	STD-3	EXP-3A	EXP-3B
30% RH	2	5	8	EXP-3A	EXP-3B	STD-3
	3	6	9	EXP-3B	STD-3	EXP-3A
0°F	1	4	7	EXP-3B	STD-3	EXP-3A
Low RH	2	5	8	STD-3	EXP-3A	EXP-3B
	3	6	9	EXP-3A	EXP-3B	STD-3

d. At the conclusion of the acclimation period, the first participant stood upon an insulated methacrylate platform and was monitored by an electrostatic charge detector. He then was discharged with radioactive bars and a check of residual charge level was made. Next, the first participant stepped from the platform and engaged in a simulated aviator work task (16 repetitions of picking up, carrying 10 feet and setting down two 25-pound loads). At the conclusion of this task, his accumulated electrostatic charge was measured before and after mounting a grounded metal platform. While remaining on the platform, decay characteristics of the electrostatic charge were determined by measuring the residual charge at short time intervals throughout 5 minutes. The first participant was electrostatically discharged; stepped from the platform; re-performed his work task; was assessed for electrostatic charge; and mounted the methacrylate platform for initial charge and decay determinations equivalent in time intervals to those measured on the metal platform. A test cycle was defined as one participant tested to include: initial charge measurement, discharge, task performance, measurement of charge, initial and decay charges while on the metal platform, discharge task performance, measurement of charge, initial and decay charges while on the methacrylate platform, and finally discharge.

e. Electrostatic charge measurements were determined daily on each of the three participants in the first group throughout 2 cycles. At the conclusion of his second daily cycle, with the participant still standing on the methacrylate platform (not discharged), measurements of electrostatic charge and decay were made of the participant after he performed each step of the following actions:

(1) At 40° F, 30 percent RH:

(a) Discarded jacket

(b) Discarded aviator's HTRN flight uniform.

(2) At 0°F, low humidity:

(a) Discarded arctic mitten set, parka w/liner and hood, and arctic trousers w/liner.

f. At the end of the third day, all participants in the first group were electrostatically monitored throughout 2 cycles after wear of each of the three types of underwear.

g. Balanced testing of the underwear continued for the first group of men from the fourth through the sixth test days in a chamber condition of 0°F, low humidity, in clothing systems described in paragraph 2.8.3b.

h. This 6-day testing schedule was repeated for the second and third groups of men.

2.8.4 Results

The results are shown in tabulated summary form in Appendix I-D.

2.8.5 Analysis

a. Because of the many variables associated with this subtest and the lack of definitive technical and procedural guidance in this field of electrostatic charge accumulation, the conclusions drawn herein are based on an overall analysis of comparison between the three combinations of clothing worn in an attempt to identify any difference in the tendency to accumulate charges due to the experimental (treated and untreated) underwear. Since it is possible that different analytical interpretations of the test data might result in significant differences in the conclusions reached, all of the raw test data will be furnished to the developer under separate cover for any useful information that might be gained in relation to this phenomenom.

b. The criteria of allowable voltage charge at 40°F was not stated for this test, but was assumed to be the same (500 volts) as stated for 0°F.

c. At 0°F, all average accumulated charges were within the allowable criteria of 500 volts. At 40°F, however, all three underwear systems gave frequent average discharges greater than 500 volts.

d. Whereas more charge accumulation might be expected at 0°F than at 40°F because of the normally reduced humidity, the reverse was observed during this test. One explanation for this occurrence might be the additional layers of material worn at the 0°F condition which might dissipate or otherwise affect the charge.

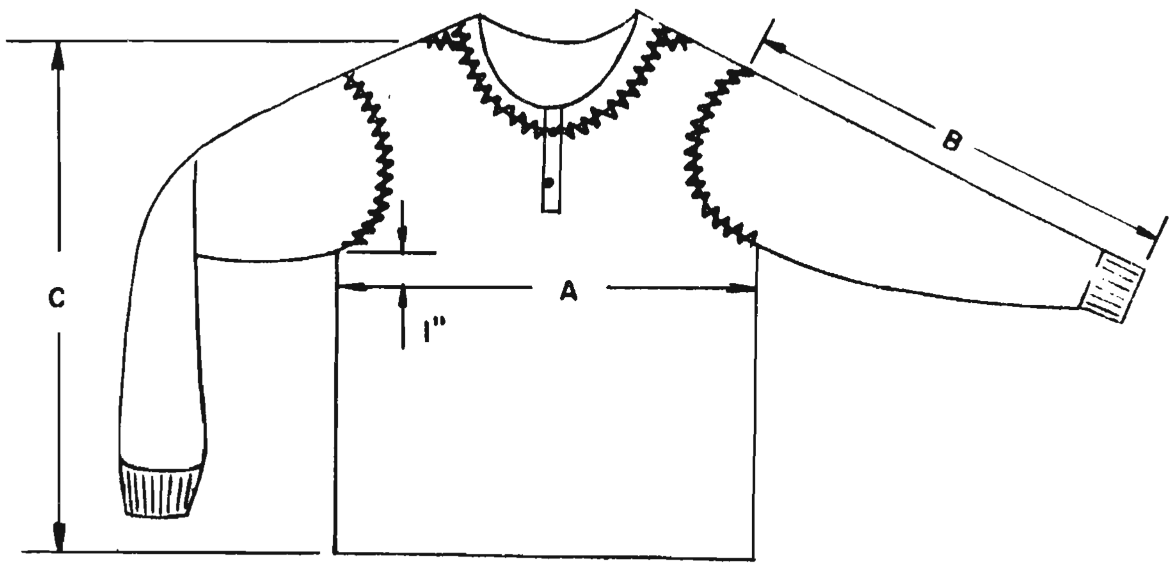
e. No trend showing significant difference between the underwear systems was apparent after the work task was performed.

f. In the makeup of the uniform combinations it should be apparent that the wool underwear was not worn with the experimental underwear since the latter is intended to replace the former. Standard summer underwear was worn next to the skin in all combinations because this is understood to be normal practice and, also, to insure comparability of test data.

SECTION 3. APPENDICES

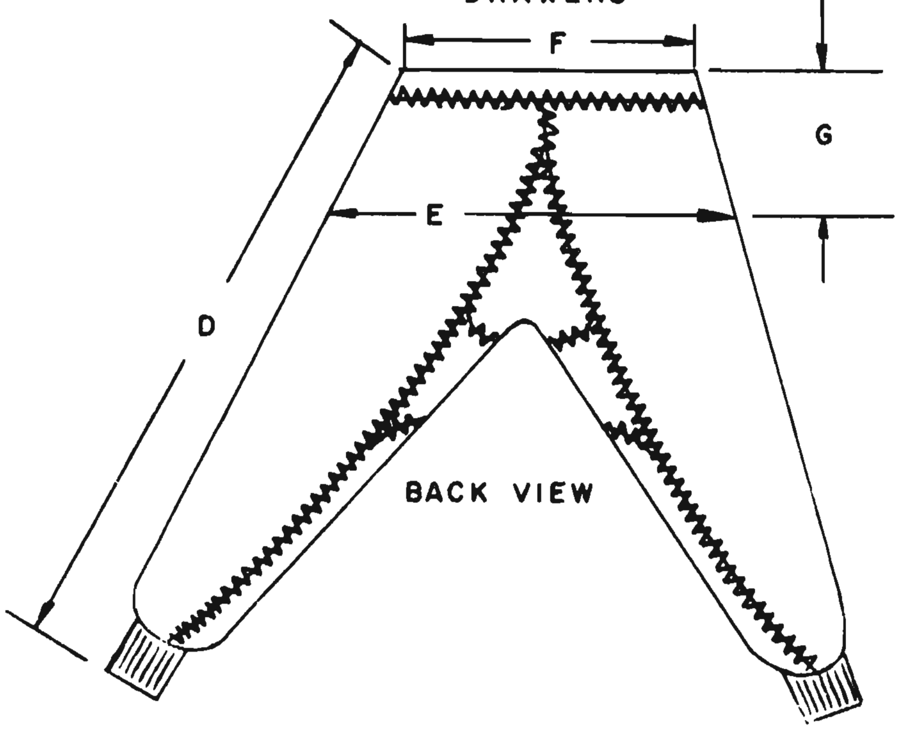
APPENDIX I-A DIAGRAM OF GARMENT MEASUREMENTS

UNDERSHIRT



FRONT VIEW

DRAWERS



THIS DIMENSION IS VARIABLE BY SIZE:

SIZE	G, INCHES
X-SML	8
SML	9
MED	10
LGE	11
X-LGE	12

APPENDIX I-A

AVERAGE GARMENT MEASUREMENTS

Size	UNDERSHIRTS MEASUREMENT IN INCHES									GARMENT WEIGHT LBS.		
	Body Width (A)			Arm Length (B)			Body Length (C)					
	Spec. Limits	Std. Avg.	Exp. Avg.	Spec. Limits	Std. Avg.	Exp. Avg.	Spec. Limits	Std. Avg.	Exp. Avg.	Spec. Target	Std. Avg.	Exp. Avg.
X-Small	13.5-15.0	14.3	15.5*	24.5-26.0	25.0	25.4	27.5 29.0	28.2	28.2	0.67	0.64	0.62
Small	15.5-17.0	15.8	16.8	25.0-26.5	25.4	25.9	28.5-30.0	28.8	28.8	0.73	0.72	0.70
Medium	17.5-19.0	17.8	19.1*	25.5-27.0	26.1	26.3	29.5-31.0	30.7	30.1	0.81	0.77	0.76
Large	19.5-21.0	19.7	20.5	26.0-27.5	25.4	26.2	30.5-32.0	31.1	31.7	0.90	0.84	0.84
X-Large	21.5-23.0	22.1	24.0*	26.5-28.0	24.3	27.6	31.5-33.0	30.1	32.2	0.98	1.15	0.84

Size	DRAWER MEASUREMENT IN INCHES									GARMENT WEIGHT LBS.		
	Overall Length (D)			Seat Width (E)			Relaxed Waist (F)					
	Spec. Limits	Std. Avg.	Exp. Avg.	Spec. Limits	Std. Avg.	Exp. Avg.	Spec. Limits	Std. Avg.	Exp. Avg.	Spec. Target	Std. Avg.	Exp. Avg.
X-Small	41.0-43.0	41.9	42.2	17.5-19.5	17.8	18.3	11.5-13.0	11.8	11.9	0.63	0.61	0.66
Small	42.0-44.0	42.7	43.4	18.5-20.5	17.7	19.3	12.5-14.0	13.4	13.3	0.67	0.64	0.66
Medium	43.0-45.0	43.8	44.5	19.5-21.5	19.9	21.5	13.5-15.0	14.3	14.3	0.71	0.70	0.73
Large	44.0-46.0	44.6	45.7	20.5-22.5	21.3	21.5	14.5-16.0	14.8	14.9	0.77	0.78	0.76
X-Large	45.0-47.0	46.0	46.9	21.5-23.5	21.4	22.3	15.5-17.0	16.7	16.0	0.83	1.04	0.76

*Denotes experimental underwear dimensions which are above specification limits.

APPENDIX I-B

TABLE I
FLAMMABILITY CHARACTERISTICS

	Std.		Exp.	
	0-Laund.	20-Laund.	0-Laund.	20-Laund.
Flame Time (secs.) 70°F, 65% RH	46.12	56.20	0.52	1.3
Glow Time (secs.) 70°F, 65% RH	0	0	6.76	3.38
Char Length (ins.) 70°F, 65% RH	12.0	12.0	2.06	1.74

TABLE II
DIFFERENTIAL THERMAL ANALYSIS

Sample	Decomposition Temperature (°C)
Body Fabric (Shirt)	440 *
Body Fabric (Pants	435
Cuff Fabric (Shirt)	440
Cuff Fabric (Pants)	440
Sewing Yarn (Shirt)	380
Sewing Yarn (Pants)	370
Label (Shirt)	350
Label (Pants)	355
Tape (Shirt	370
Tape (Pants)	370
Elastic (Pants)	420

* 440° as the decomposition ~~time~~ temperature for the basic body fabric constituted the lower thermal degradation property required by the criteria.

TABLE III
SURFACE RESISTIVITY (ALL FIGURES ARE X 10^{12} OHMS)

	Std.		Exp.	
	0-Laundering	20-Launderings	0-Laundering	20-Launderings
70°F, 25% RH	3.3560	0.8580	232.8	2465.0
70°F, 65% RH	0.1200	0.0290	248.2	6879.6
70°F, 85% RH	0.0015	0.0004	16.16	861.2

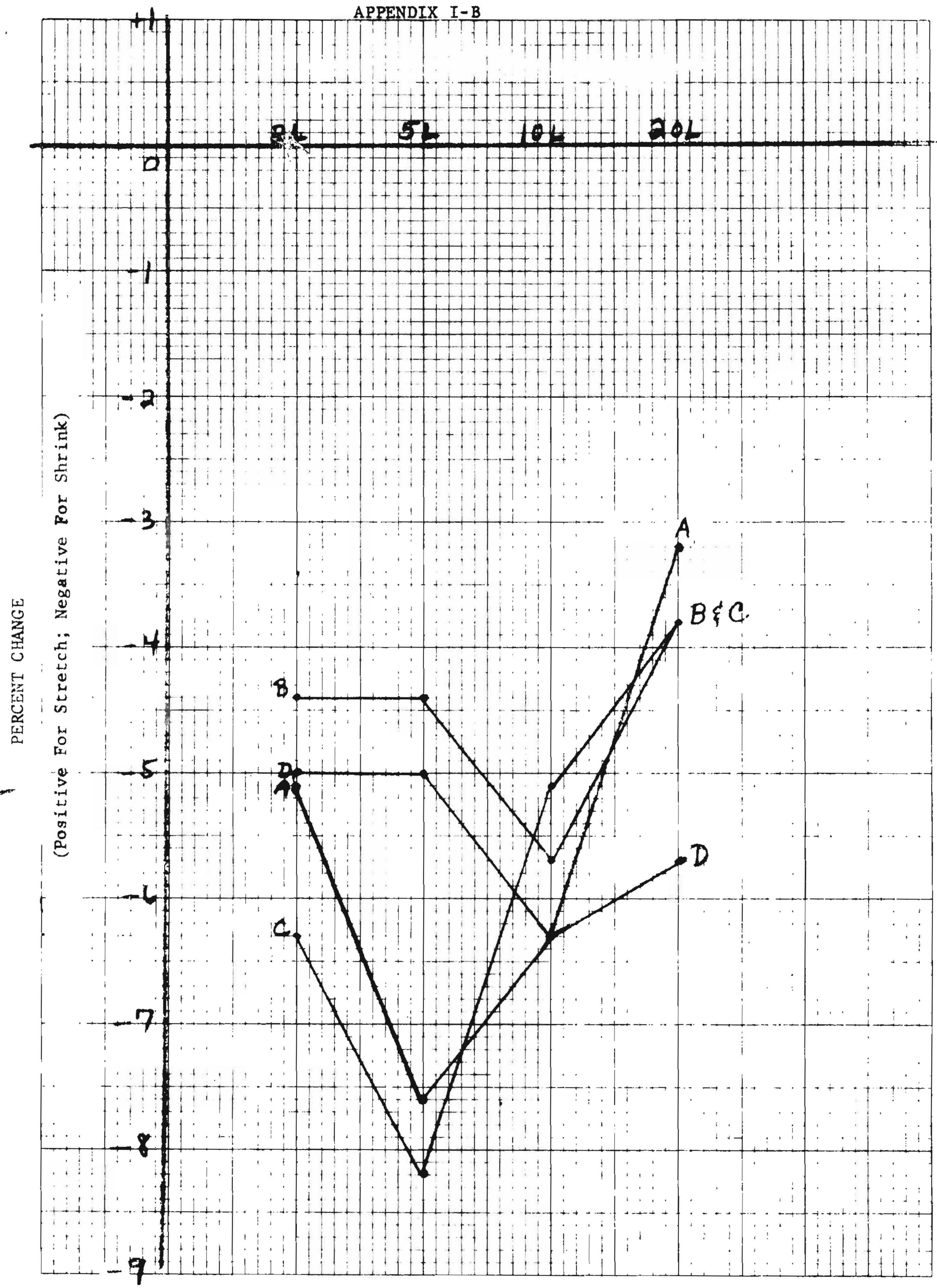


Figure 1. Fabric Average Percent Change

APPENDIX I-B

AVERAGE FABRIC SHRINKAGE

MEASUREMENT		INCHES A	B	C	D	(Refer to Sides of Rectangular Samples)
New	Average	9 14/16	9 14/16	9 14/16	9 15/16	
After 2L	Average	9 6/16	9 7/16	9 4/16	9 7/16	
	Percent) Change)	-5.1	-4.4	-6.3	-5.0	
After 5L	Average	9 2/16	9 7/16	9 1/16	9 7/16	
	Percent) Change)	-7.6	-4.4	-8.2	-5.0	
After 10L	Average	9 4/16	9 5/16	9 6/16	9 5/16	
	Percent) Change)	-6.3	-5.7	-5.1	-6.3	
After 20L	Average	9 9/16	9 8/16	9 8/16	9 6/16	
	Percent) Change)	-3.2	-3.8	-3.8	-5.7	

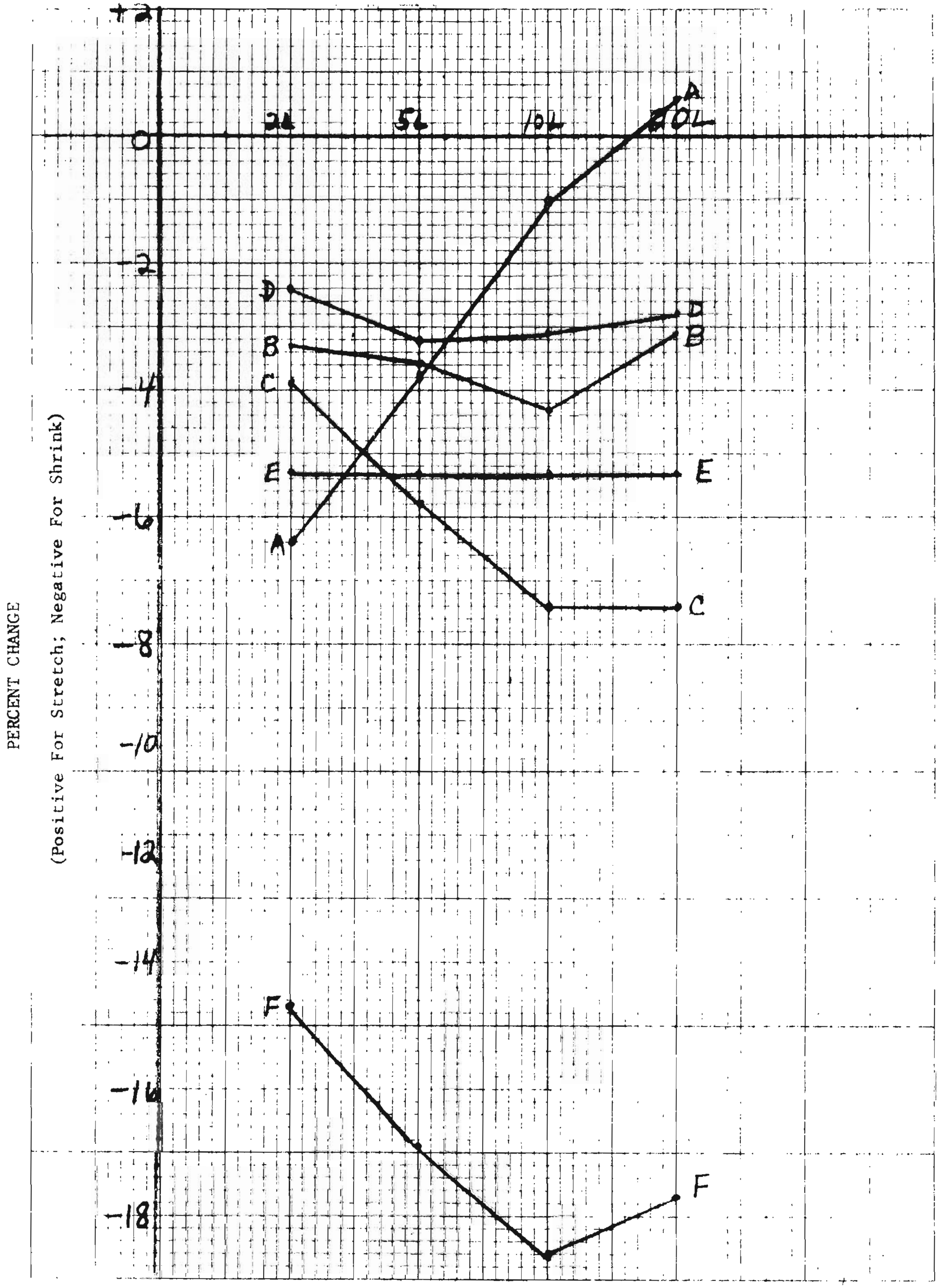


Figure 2. Garment Average Percent Change

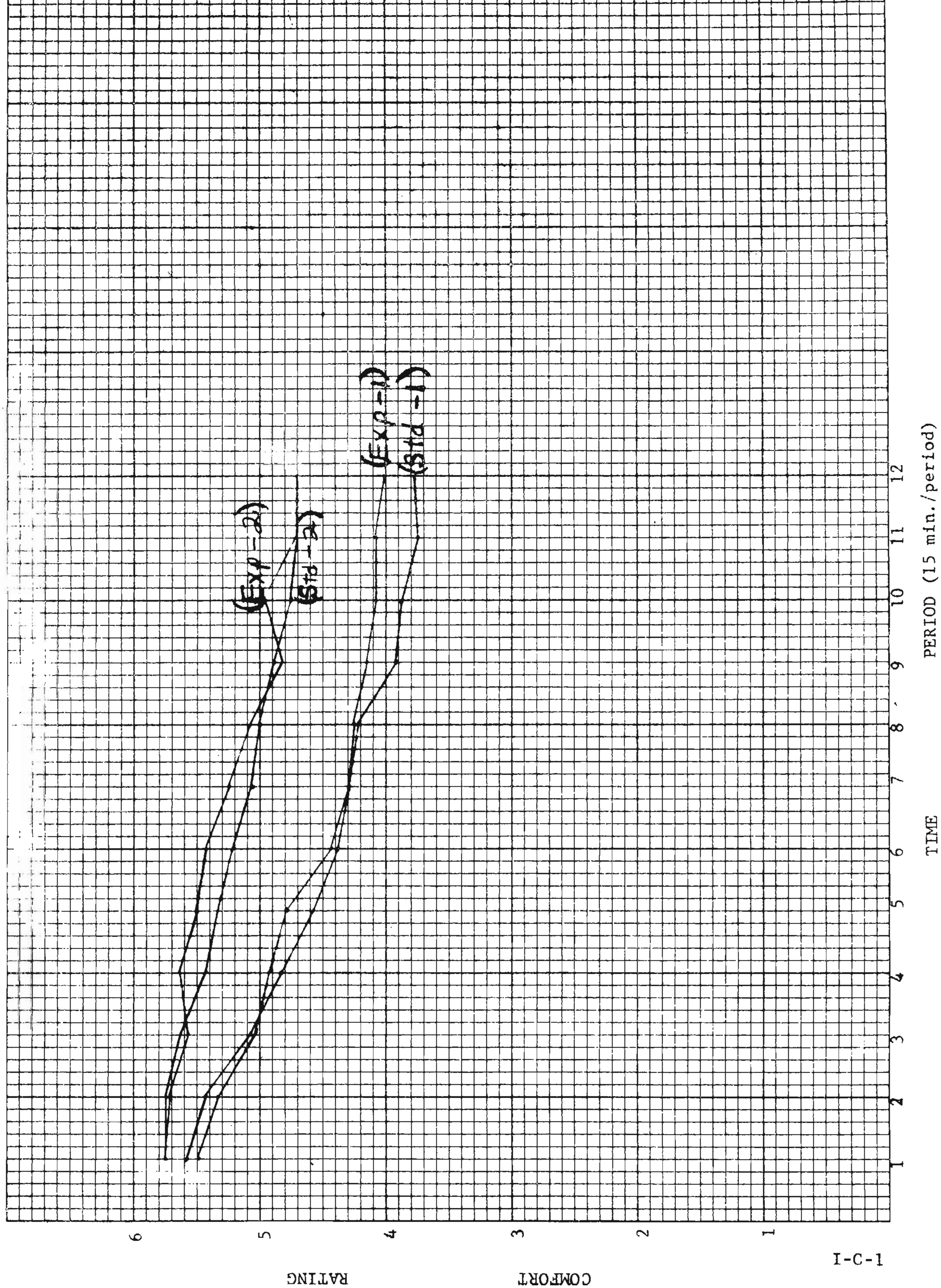
APPENDIX I-B

GARMENT SHRINKAGE

MEASUREMENT		A	B	C	D	E	(Refer to) (App I-B) F
New	Average	19 10/16	26 6/16	30 5/16	44 11/16	21 3/16	14 7/16
After 2L	Average	18 6/16	25 8/16	29 2/16	43 10/16	20 1/16	12 5/16
	Percent) Change)	-6.4	-3.3	-3.9	-2.4	-5.3	-14.7
After 5L	Average	18 14/16	25 7/16	28 9/16	43 4/16	20 1/16	12 0/16
	Percent) Change)	-3.8	-3.6	-5.8	-3.2	-5.3	-16.9
After 10L	Average	19 7/16	25 4/16	28 1/16	43 5/16	20 1/16	11 12/16
	Percent) Change)	-1.0	-4.3	-7.4	-3.1	-5.3	-18.6
After 20L	Average	19 12/16	25 9/16	28 1/16	43 7/16	20 1/16	11 14/16
	Percent) Change)	+0.6	-3.1	-7.4	-2.8	-5.3	-17.7

APPENDIX I-C

Environmental Comfort Data



APPENDIX I-D

ELECTROSTATIC MEASUREMENTS (VOLTS)
(All figures shown are based upon absolute values with no delineation between positive - negative polarities)

Temperature	40°F												0°F											
Electrostatic Charge	Volts												Volts											
Type Garment	Std				Exp-A[1]				Exp-B[2]				Std				Exp-A[1]				Exp-B[2]			
	Max	Min	Avg	% > 500	Max	Min	Avg	% > 500	Max	Min	Avg	% > 500	Max	Min	Avg	% > 500	Max	Min	Avg	% > 500	Max	Min	Avg	% > 500
End of Acclimation	2120	96	859.44	72.2	2120	0	785.00	66.7	1925	38	796.39	55.6	960	0	304.17	16.7	1440	0	331.58	16.7	1250	0	255.19	18.8
Completion of Work Tasks	290	0	69.22	0	370	0	64.97	0	365	0	114.58	0	134	0	42.29	0	385	0	59.96	0	211	0	48.90	0
Decay Characteristics																								
Metal Platform																								
0 secs	423	0	119.67	0	476	0	97.56	0	580	0	135.11	5.6	173	0	51.00	0	500	0	81.50	0	250	0	54.00	0
15 secs	404	0	109.83	0	457	0	91.17	0	540	0	117.89	5.6	115	0	41.42	0	460	0	70.25	0	134	0	37.13	0
30 secs	347	0	96.17	0	420	0	80.33	0	520	0	109.44	5.6	115	0	28.67	0	404	0	60.83	0	96	0	22.75	0
45 secs	250	0	79.67	0	420	0	72.06	0	480	0	97.44	0	96	0	27.08	0	404	0	54.50	0	58	0	15.63	0
60 secs	192	0	68.06	0	420	0	66.67	0	460	0	91.22	0	96	0	20.75	0	404	0	46.42	0	58	0	8.44	0
85 secs	170	0	60.83	0	400	0	62.39	0	440	0	85.67	0	77	0	19.17	0	404	0	44.83	0	58	0	8.44	0
Plastic Platform																								
0 secs	2400	77	739.00	61.1	1920	0	826.89	61.1	2400	39	933.44	55.6	1440	96	430.33	25.0	1440	0	206.42	8.3	1250	0	204.31	12.5
15 secs	2400	56	733.28	55.6	1830	0	791.78	61.1	2310	19	839.28	50.0	1440	0	361.17	16.7	1440	0	192.00	8.3	1150	0	159.69	8.3
30 secs	2400	38	717.50	55.6	1636	0	736.44	61.1	2310	0	815.17	50.0	1440	0	325.83	16.7	1440	0	179.17	8.3	1150	0	134.31	8.3
45 secs	2400	0	697.27	55.6	1540	0	715.39	61.1	2213	0	785.17	50.0	1340	0	290.58	16.7	1440	0	160.00	8.3	960	0	111.63	8.3
60 secs	2400	0	677.11	55.6	1540	0	700.94	61.1	1925	0	744.28	50.0	1340	0	289.00	16.7	1440	0	155.17	8.3	770	0	86.50	8.3
85 secs	2400	0	669.44	50.0	1540	[illegible]	651.06	61.1	1925	0	698.61	50.0	1340	0	280.92	16.7	1440	0	153.58	8.3	673	0	70.81	8.3
Removal of Clothing 40°F																								
Flight Jkt & Gloves	4500	867	2279.56*	100	3560	192	1926.78*	88.9	4600	481	2547.00*	88.9												
Aviator's HTRN Uniform	2400	38	797.11	33.3	4523	38	1124.33	50.0	3850	58	1137.22	41.7												
0°F																								
Arctic Layer													865	38	365.33	33.3	712	19	234.00	16.7	3270	19	536.00	16.7

*Results exceeded criteria significantly.

[1] Exp A is untreated
[2] Exp B is treated

APPENDIX I-E

AD____________________

USAARL REPORT NO. 71-19

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION

BY

Francis S. Knox,III
George R. McCahan, Jr.
Thomas L. Wachtel
Walter P. Trevethan
Andrew S. Martin
David R. DuBois
George M. Keiser

June 1971

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

Fort Rucker, Alabama 36360

NOTICE

Qualified requesters may obtain copies from the Defense Documentation Center (DDC), Cameron Station, Alexandria, Virginia. Orders will expedited if placed through the librarian or other person designated to request documents from DDC (formerly ASTIA).

Change of Address

Organizations receiving reports from the US Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

This document has been approved for public release and sale; its distribution is unlimited.

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

FOREWORD

Research discussed in this report was accomplished between November 1970 and June 1971 by the Bioengineering and Evaluation and Aviation Medicine Divisions as part of USATECOM project No. 4-EI-485-AAC-008 with reimbursible funds transferred by DA Form 2544 No. 38-71 USAGETA, Fort Lee, Virginia dated 9 December 1970.

In conducting this research, the investigators adhered to the "Guide for Laboratory Animals Facilities and Care" prepared by the committee on the Guide for Laboratory Animals Facilities and Care, National Academy of Sciences, National Research Council. Humane procedures were utilized throughout and a graduate veterinarian was in constant attendance to perform all surgical procedures and to ensure that all animals were fully anesthetized and insensitive to pain.

ACKNOWLEDGMENT

The authors are deeply indebted to COL Gilbert L. Raulston, VC, US Army, LTC Basil Pruitt, MC, US Army, Dr. F. D. Foley, Brooke Army Medical Center, Jack M. Becker and Steven Stadnicki, Fort Lee, Virginia, Donald Biggerstaff, TUSA Training Aids Center, Fort Rucker, Alabama, and all involved USAARL personnel for their generous assistance without which this project could not have been completed.

AD________________________

USAARL REPORT NO. 71-19

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION

BY

Francis S. Knox, III
George R. McCahan, Jr.
Thomas L. Wachtel
Walter P. Trevethan
Andrew S. Martin
David R. DuBois
George M. Keiser

June 1971

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

Fort Rucker, Alabama 36360

U. S. Army Medical Research and Development Command

ABSTRACT

This report describes the use of a bioasssay technique to evaluate the fire resistant and thermal protection capabilities of the lightweight underwear of the Army winter flight clothing system. Samples of fabrics under consideration for inclusion in the Army winter flight clothing system were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a flame source calibrated to simulate a well developed JP-4 fire. Exposure times of 1.75, 3.50, and 7.0 seconds were used.

Evaluation of resultant skin burns shows that none of the fabric systems, as evaluated, meet the essential requirement of 10 seconds protection. Single-layered fabric (Nomex shell fabric) offers slight protection and double-layered fabric systems (Nomex outer shell with either Nomex underwear or 50% cotton/50% wool underwear) offer more than three times the protection of single layers, but still fail to provide 10 seconds of protection. The 50% cotton/50% wool underwear offers equal or better protection than experimental Nomex underwear worn under standard Nomex outer shell. Washing does not affect thermal protection. The data further indicate that the method using pigs provides a very consistent and meaningful way of evaluating thermal protective fabrics.

APPROVED: ROBERT W. BAILEY
COLONEL, MS
Commanding

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF TABLES AND FIGURES

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION

INTRODUCTION

During fiscal year 1969, there were 133 noncombat aircraft accidents involving UH-1 Army helicopters in which 167 individuals received major injuries and 234 individuals died. Twelve of the 167 major injuries and 64 of the 234 fatalities were due to burns. The minimum total cost of these injuries and deaths due to burns is $2,730,763.(1,2) Aside from purely humanitarian considerations it is evident that the cost of replacing aircrewmen incapacitated or killed in post crash fires is of major proportions. Currently flight clothing systems can be designed to provide some thermal protection; however, they may not provide adequate thermal protection.

Our concept of adequate thermal protection is defined as: that level of protection sufficient to allow an uninjured aircrewman to egress while receiving minimal (20% body area) second and third degree burns from a downed aircraft surrounded by a fully developed fuel fire. This level of protection was chosen for purposes of discussion because it would result in at least 90% survival of aviators between the ages 20 and 50 who received prompt care at a major burn center.(3) To date it has not been possible to define, precisely, escape time from crashed and burning helicopters. It is, therefore, difficult to set an essential level of thermal protection. In 1966, 10 seconds of protection was considered essential.(4) It is against this standard that proposed clothing sytems must be judged.

The following experiment was designed in an effort to control the thermal source and to quantify, better, the degree of burn protection provided by candidate thermal protective flight clothing materials. Samples of fabric under consideration for inclusion in the Army winter flight clothing system were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a calibrated flame source for various periods of time. Macroscopic (gross) and microscopic (micro) evaluation of tissue damage under the fabric samples indicated the degree of protection afforded by each.

This method was used to test the relative merits of experimental underwear (Nomex) and 50% cotton/50% wool long underwear when worn with the single-layered, U.S. Army standard A flight suit.

METHODS AND MATERIALS

Animals

Domestic, white, male and female pigs, weighing an average of 46 kg (38.6 to 56.8 kg) were locally procured quarantined, and verified to be healthy and free of internal parasites prior to use in this study. Pigs were chosen because their skin more closely resembles human skin than any other commonly used or available laboratory animal.(5) During the quarantine period the pigs were kept in the shade to prevent sunburn. The hair was closely clipped with a #40 clipper head at least two days prior to the study. Several hours prior to an experiment the test area was washed with running water and carefully dried.

Anesthesia

All pigs were premedicated with 100 mg Sernylan (phencylidine hydrochloride - Parke-Davis) and 50 mg Thorazine (chlorpromazine hydrochloride - Pitman-Moore) (both in the same syringe and administered intramuscularly in the right hip) followed by Penthrane (methoxyflurane - Abbott) anesthesia.* Atropine sulfate (0.8 mg/pig, subcutaneous) was routinely used.

When cutaneous sensation had disappeared (determined by the scratch test), the experimental animal was transported from the vivarium to the test site on a specially constructed transporting device. The experimental animal was maintained in Stage III anesthesia on Penthrane and oxygen except during the actual exposure when a Penthrane nose cone was used. Every possible safety precaution was taken to lessen the potential fire hazard of Penthrane and oxygen.

Fire Wall, Shutter System, Template

After reaching the test site, the transporting device holding the pig was positioned behind a hard asbestos (Transite) fire wall. (Figure 1) This wall protected the pig

---

*See equipment list for all major items.

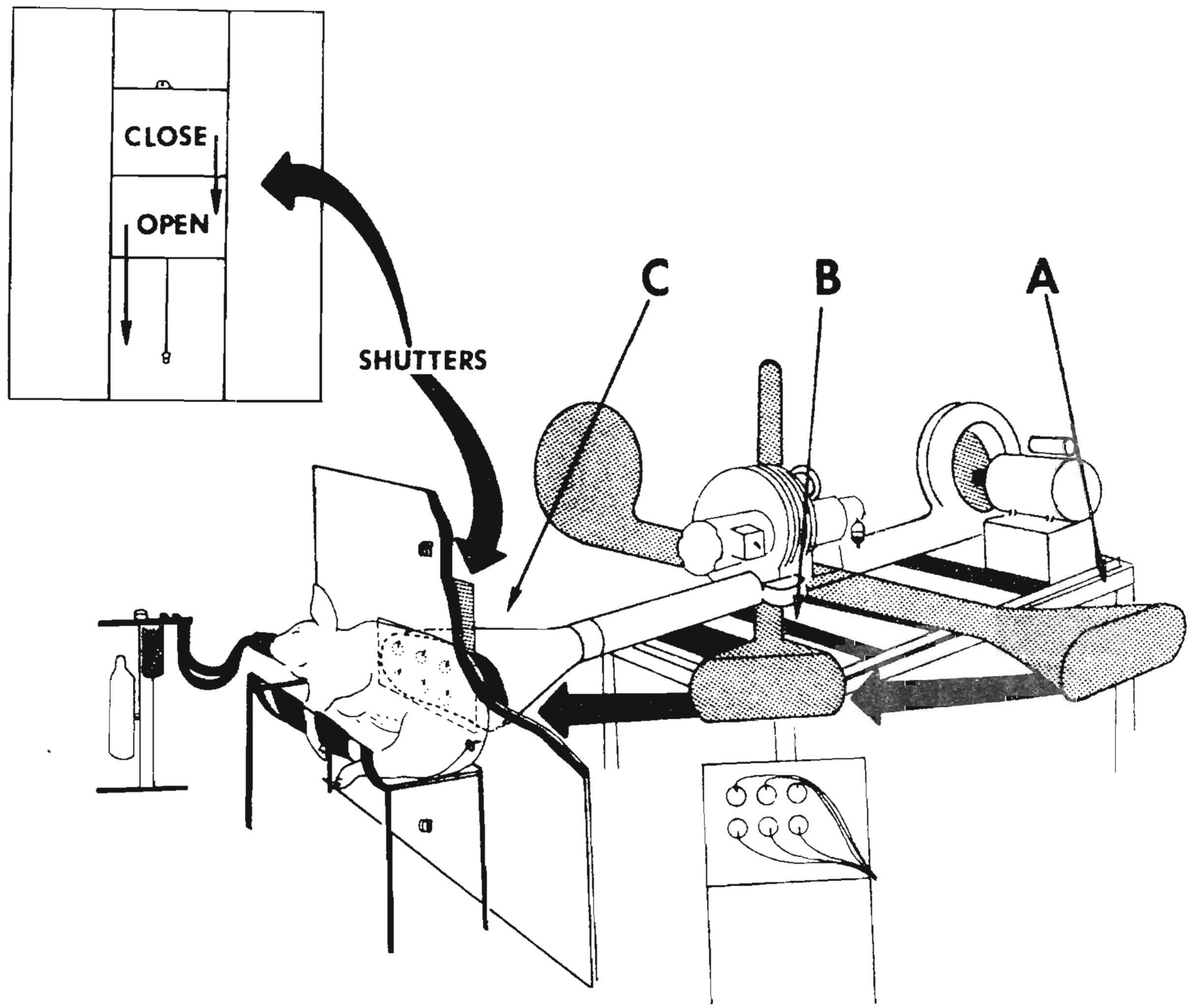


FIGURE 1. Experimental apparatus showing the flame gun, thermal barrier with shutter system, pig in transporting device, and thermocouples for steady-state temperature data. Position A is for warm-up, position B is for steady-state flame temperature determinations, and C is the position of the flame gun during an experiment.

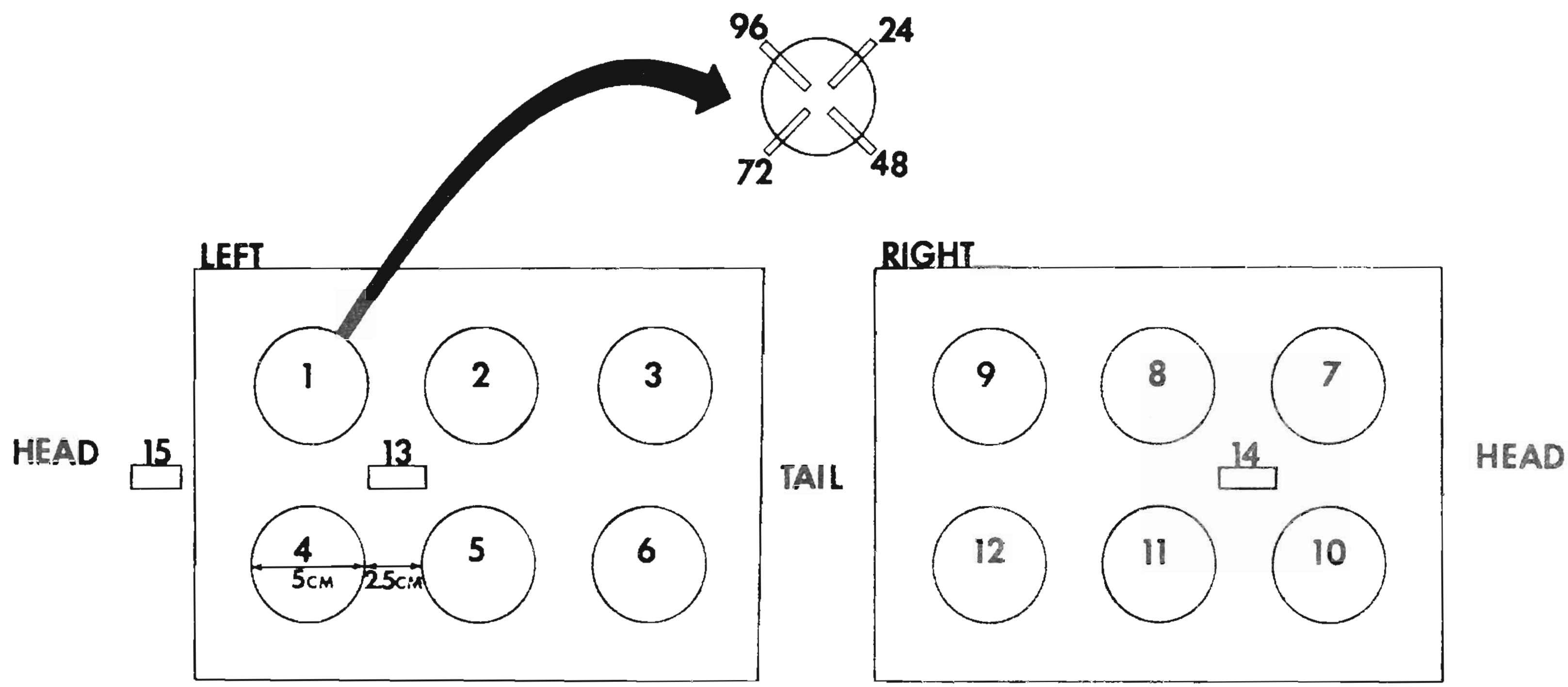


FIGURE 2. Template showing size, location, and code number for each test site. The insert shows the orientation of the incisional biopsies made at each site.

and contained a rectangular aperture through which flame could pass. Passage of the flame was controlled by a double guillotine shutter held in the closed position by pins welded to solenoids. Flame front configuration was changed from a single large rectangle to six 2 inch diameter circles (Figure 2) by positioning a Transite template over the aperture in the fire wall.

To begin an experiment, the left side of the animal was placed against the Transite template. (Figure 1) When properly aligned, a wooden template of exactly the same pattern and alignment was sandwiched between the subject and the Transite. The wooden template insulated the pig from the Transite which acted as a nonflammable thermal conductor. Without this insulation the hot Transite produced skin burns. Each hole in the wooden template was covered by a fabric sample (or left uncovered as a control) and instrumented with an unshielded, 0.005 inch chromel/alumel thermocouple. (Figures 9 and 10) The position of the fabric samples was systematically varied to neutralize any position effect. The proximity of the pig's side to the test site was checked to assure proper alignment without pressure on fabrics or gaps for flame leakage.

Flame Gun

As the pig was being anesthetized the flame gun (modified gun-type - conversion oil burner) was set to deliver 14 ± 0.5 $BTU/ft^2/sec$ and was calibrated against water-cooled calorimeters. This level of heat flux simulates a worst credible thermal environment (a well developed JP-4 fire). Such an environment cannot readily be simulated with a standard Meker burner. The kerosene fuel produces a sooty flame whose chemistry simulates a JP-4 fire more closely than natural gas.(6)

After the pig was in position next to the wooden template, the flame gun was ignited at a neutral position (Position A, Figure 1) and allowed to warm up for two minutes until it reached a steady-state. The gun was then moved to impinge on a bank of thermocouples (Position B, Figure 1) until all thermocouples indicated steady-state temperatures. The flame was next moved to the test site (Position C, Figure 1). After one or two seconds, the first solenoid was manually activated opening the shutter and exposing the template. After a predetermined time of 1.75, 3.50, or 7.0 seconds, a second solenoid was automatically activated, thereby closing the shutter. Exposure times were selected by exposing three pigs to the flame for various times between 1.0 and 5.0 seconds. After selecting 3.5 seconds as the middle time, 1.75, and 7.0 seconds were chosen as one half and twice the middle time, respectively. The time of exposure was recorded on a recording oscillograph and on a calibrated stop clock activated by signals from the solenoids. A manual stop watch provided additional back up. Following the test exposure, the flame was returned to the bank of thermocouples (Position B, Figure 1) for post-burn temperature determinations. When the thermocouples reached a stable state the flame was extinguished.

The pig was moved away from the template shortly after the closing of the second shutter. The burn procedure was then repeated on the right side of the subject using new Transite and new wooden templates. Following the exposures the subject was returned to the vivarium for post anesthetic care, photography, and gross evaluation of burns.

Post Exposure Procedures

Photographs of burned areas were taken immediately post-burn, at two hours, and at 24 hours. The surface appearance of each burn site was drawn by a medical illustrator at 2 and 24 hours post burn. These drawings were used to pinpoint the exact position of a biopsy and to determine the gradations of damage included in each specimen.

Burn Evaluation

The severity of the cutaneous burn lesions was evaluated by two methods. First, the surface appearance was graded immediately, at two hours, and at twenty-four hours by two physicians (a surgeon with experience at a burn center and an internist) and one veterinarian. Second, microscopic tissue damage was assessed by a veterinary pathologist using serial, incisional biopsies taken at 24, 48, 72, and 96 hours with the pig under Penthrane anesthesia. (See Figure 2 for the location of the biopsies.)

The scheme for grading the surface appearance of burns developed by this Laboratory closely parallels the work of the University of Rochester.(7) The mildest surface change (Stage 1) observed was erythema, while the most severe (Stage 6) was carbonization. In between, one could detect four stages:

Stage 2 - a transient purple-circulatory stasis stage which either progressed to patchy coagulation or regressed to a red burn by 24 hours.

Stage 3 - uniform coagulation.

Stage 4 - steam blebs and destroyed blebs.

Stage 5 - partial carbonization or leathery brown burn.

These six conditions formed a basis for grading tissue damage. (Table II) Furthermore, it was also possible to discern smaller increments of each major gradation and these smaller transitions were recorded as (+) or (-) the major grade. The most severe, least severe, and overall grade were recorded for each burn site. The 24 hour overall grade, a concensus of the three observers, was used in the statistical analyses.

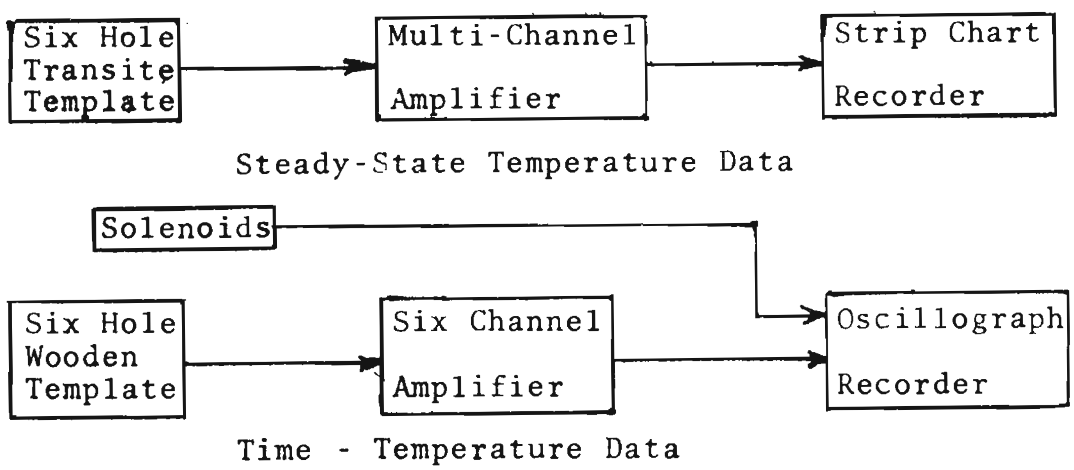
Histopathology

Tissue specimens were fixed in unbuffered 10% formalin and forwarded to the Veterinary Pathology Department of the Naval Aerospace Medical Research Laboratory, Pensacola, Florida, where the following procedures were performed. Fixed tissue specimens were labeled, dehydrated, embedded in hematoxylin and eosin using the method developed at the Armed Forces Institute of Pathology(8) as modified by the Naval Aerospace Medical Research Laboratory.

The completed slides were graded by a veterinary pathologist. From this verbal description of tissue damage and degree of burn it was possible to assign a number which corresponded to the degree of burn. These numbers ranged from 0 to 6.0 in the same way as those used for gross burn evaluation.

Instrumentation

Two types of thermocouple data were recorded during the experiment. The first was the steady-state temperature of the flame impinging upon the template measured at four of six possible locations. The second was the time-temperature history of the pig skin-air interface, protected and unprotected by different clothing ensembles. The block diagram of the two data acquisition systems is shown in Figure 3.



BLOCK DIAGRAM OF DATA ACQUISITION SYSTEM

FIGURE 3

A six hole template was constructed of Transite and instrumented with chromel/alumel thermocouples. (Figure 3) Since transient temperatures and time delays were of no interest here, thick (0.032 inch) and durable thermocouples were used.

The outputs of four of the six thermocouples were amplified and recorded on a strip chart recorder. The complete data train (including 30 ft. of cable) was calibrated using a precision voltage source. This was done to insure that resistive forces in the wire and small nonlinearities in the amplifier and recorder would be accounted for.

The sensors used in the six hole wooden template (Figure 3) were small diameter (0.005 inch) chromel/alumel thermocouples to insure fast response time. They were changed after every burn to eliminate any possibility of their being damaged by the high temperatures. These thermocouples were connected to a six channel amplifier with built-in thermocouple cold junction compensators. The output of the amplifier was connected to a recording oscillograph.

Signals from the solenoids used to operate the shutter system were recorded on the oscillograph directly so that an accurate timing signal would be present on the final oscillograph record. This data acquisition system was calibrated using the same precision voltage source as used previously.

RESULTS

A total of 22 pigs were obtained for use in this study. Of these three were used in a pilot procedure to practice technique and to determine appropriate exposure times. Two others did not meet requirements for standard healthy pigs and were not used. The remaining 17 pigs were distributed among the three experimental groups as follows: 1.75 second exposure, 5 pigs; 3.5 and 7.0 second exposures, 6 pigs each. A power failure occurred during exposure of the left side of one pig (3.5 second group). The resultant exposure was only 2.29 seconds, so the data for this side are not included in the results.

Just prior to each test, the flame gun output was calibrated at each of four template locations (Positions 1,3,4, 6, Figure 2) using water-cooled calorimeters. The mean heat flux ± one standard deviation for each position and for all positions combined are presented in Table I.

TABLE I

FLAME GUN CALIBRATION DATA
HEAT FLUX MEAN ± STD DEVIATION

POSITION (Fig. 2)	BTU $FT^{-2} \cdot SEC^{-1}$	$CAL \cdot CM^{-2} \cdot SEC^{-1}$
1	13.81±0.65	3.74±0.18
3	13.47±0.51	3.65±0.14
4	14.24±0.51	3.86±0.14
6	14.41±0.47	3.91±0.13

The degree of burn (0-6.0 scale, Table II) experienced by the pigs for each combination of protective fabric and exposure duration is presented in Figure 4. These burn values represent the average of the 24 hour gross evaluations for each experimental group. There is a tendency for burns (Figure 4) to become more severe with increasing exposure duration and decreasing number of protective layers.

To illustrate the effect of washing on the protective performance of given fabric systems, the data for washed and

TABLE II

GRADING SYSTEM FOR GROSS BURN EVALUATION

LABORATORY GRADE	SURFACE APPEARANCE	ADDITIONAL INFORMATION	DESCRIPTIVE TERM	HUMAN EQUIVALENT
0	Normal Skin	Normal Skin	Normal Skin	No Burn
1	Erythema	Painful Pliable Hyperemia No Blisters Skin hot to touch	Red Burn	Epidermal
2	Patch Coagulation (Mottled Red)	Painful Pliable Cap. Refill Possible No blisters Skin hot to touch	Spotted White Burn	Superficial Intra-dermal
3	Uniform Coagulation (Pearly White)	Pliable Little Pain ± Blister (early) Skin Temp normal	White Burn	Deep Intradermal
4	Steam Bleb early blebs ruptured blebs ruptured blebs with charring	Blisters Moderately Pliable No Pain Skin Temp normal	Blebbed White Burn	Superficial Sub-dermal
5	Leathery Brown	Nonpliable Cold, Hard Insensitive Thrombosed Vasculature	Leathery Brown Burn	Deep Subdermal
6	Carbonization	Hard - Fat or Muscle Burned	Charred Black Burn	Very Deep Sub-dermal

unwashed fabric systems are plotted separately (Figure 4). The remaining results (Figure 5) will be presented in combined form, ie, washed plus unwashed.

Microscopic evaluation of tissue excised from each burn site revealed the average degree of burn (Figure 5) becomes more severe with increasing exposure and decreasing number of protective layers. These data are similar to those presented in Figure 4 with the exception that at 7.0 seconds the data for all treatment groups tends to cluster about one burn level (4.0).

During each exposure the temperature of the fabric-skin interface was recorded as a function of time. Figures 6,7, and 8 show these time-temperature histories for exposures of 1.75, 3.50, and 7.0 seconds, respectively. These records were chosen because they are particularly clear and illustrate features seen in most other records. By comparing the burn evaluations in Table III with the appropriate time-temperature curve, it becomes apparent that the area under the curve is related to the degree of burn. Apparently the only observations inconsistent with this inference are the microscopic evaluations for Nomex and Nomex/Nomex (7.0 sec). They are reversed (Nomex/Nomex>Nomex) when compared with both the gross evaluations (Nomex>Nomex/Nomex) and the areas under the time-temperature curves. This discrepancy is accounted for, however, because the medical illustrations show the biopsies from these burn sites may not have been typical of the entire site.

Figures 9a - 11c are photographs of burn sites at 24 hours post-burn and the front (flame) and back (pig) sides of the protective fabric systems. These photographs show the fabric condition and tissue destruction which occurred in the experiments from which the time-temperature curves (Figures 6-8) were taken. Note that Nomex shell fabric failure proceeds from the center outward.

Various levels of burn, from 0 to 6.0 are represented in Figures 9a, 10a and 11a. The control or unprotected site is always the most severely burned, while sites protected by Nomex/Standard are the least damaged. Tissue between sites is totally free of damage indicating that the template protected the pig. Each burn is clearly circumscribed with minimal edge effect.

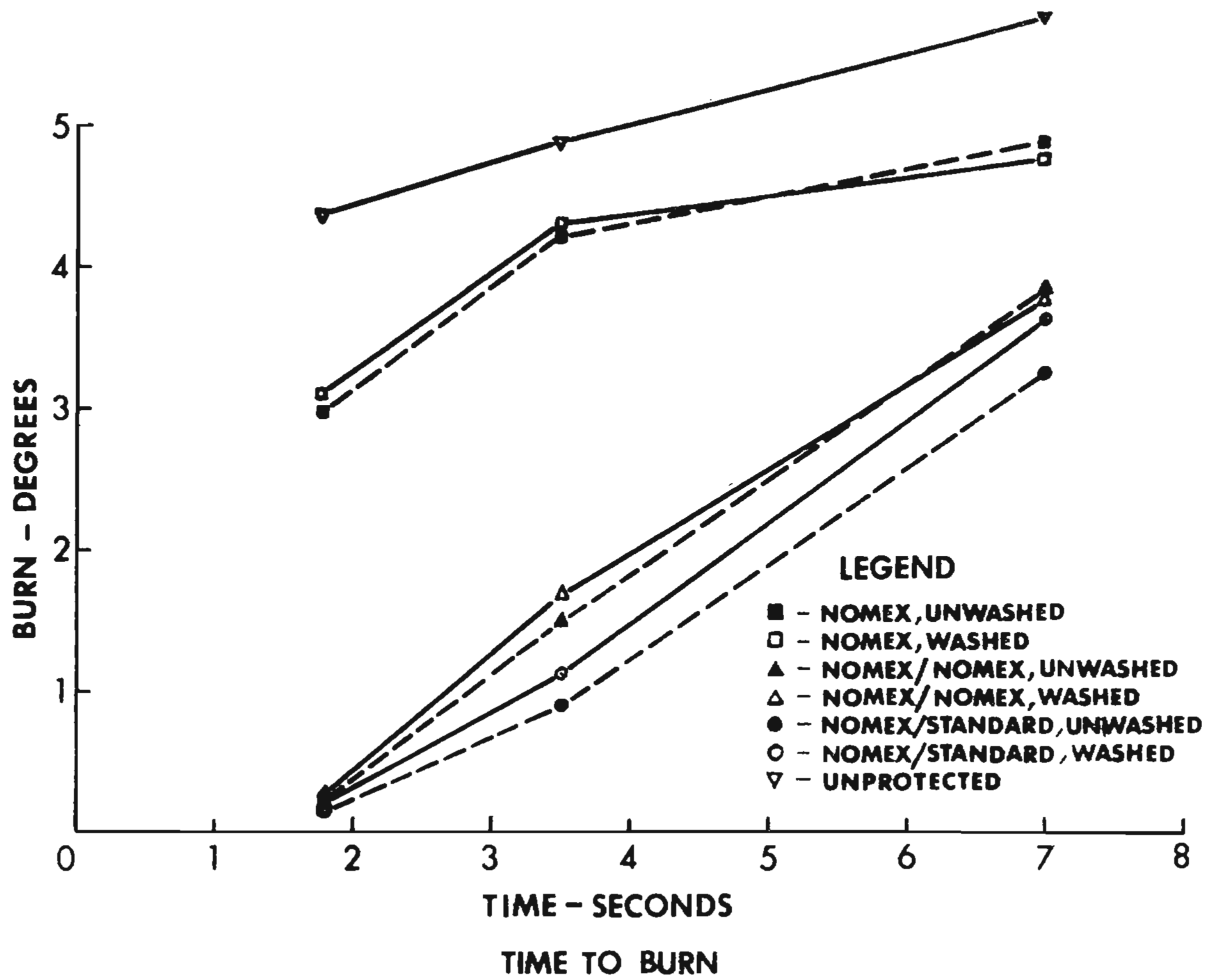


FIGURE 4. Average degree of burn (gross evaluation) vs exposure time.

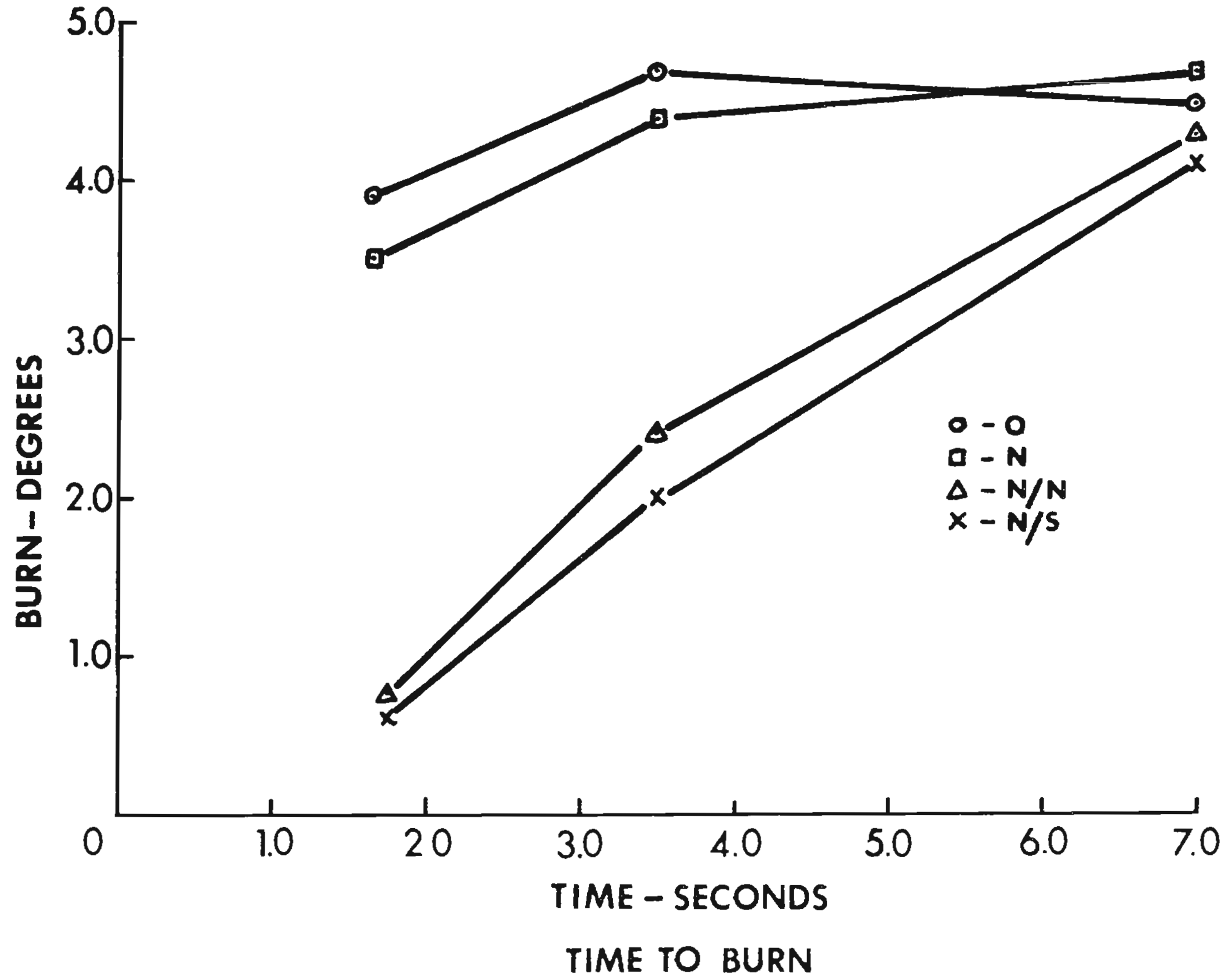


FIGURE 5. Average degree of burn (microscopic evaluation) vs exposure time.

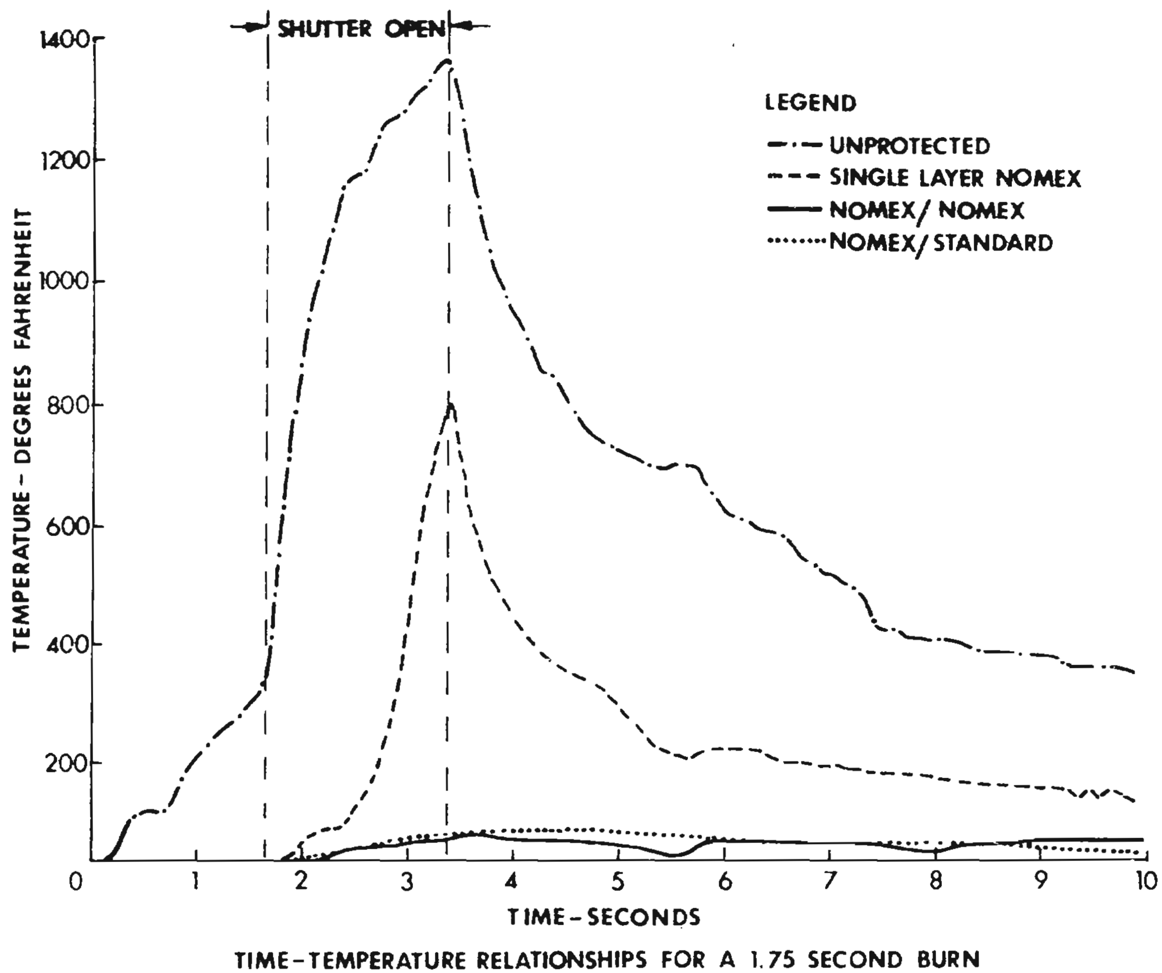


FIGURE 6. These representative temperatures were measured by a thermocouple placed between the fabric and the skin at the center of each test site. The temperature rise which occurred before the shutter opened is due to the heating of the shutter by the flame gun.

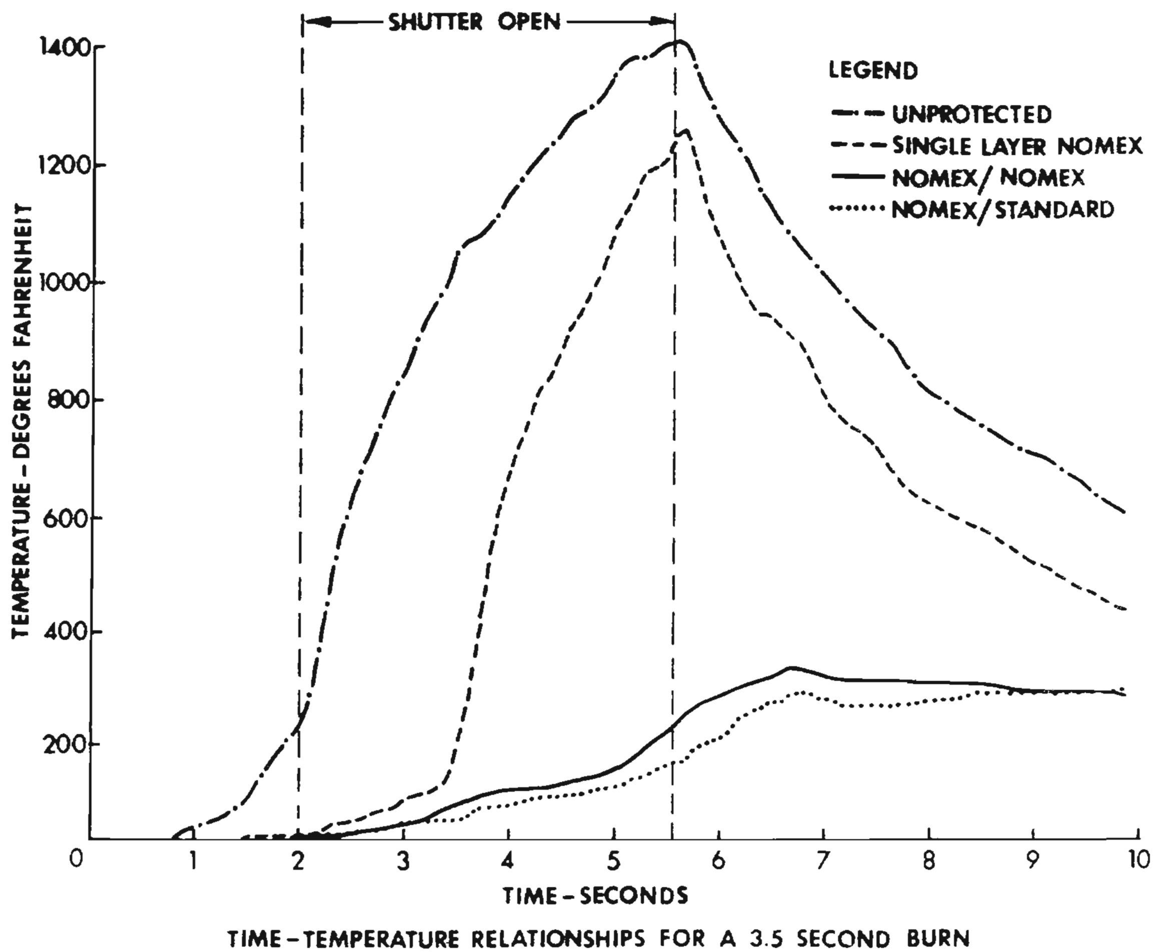
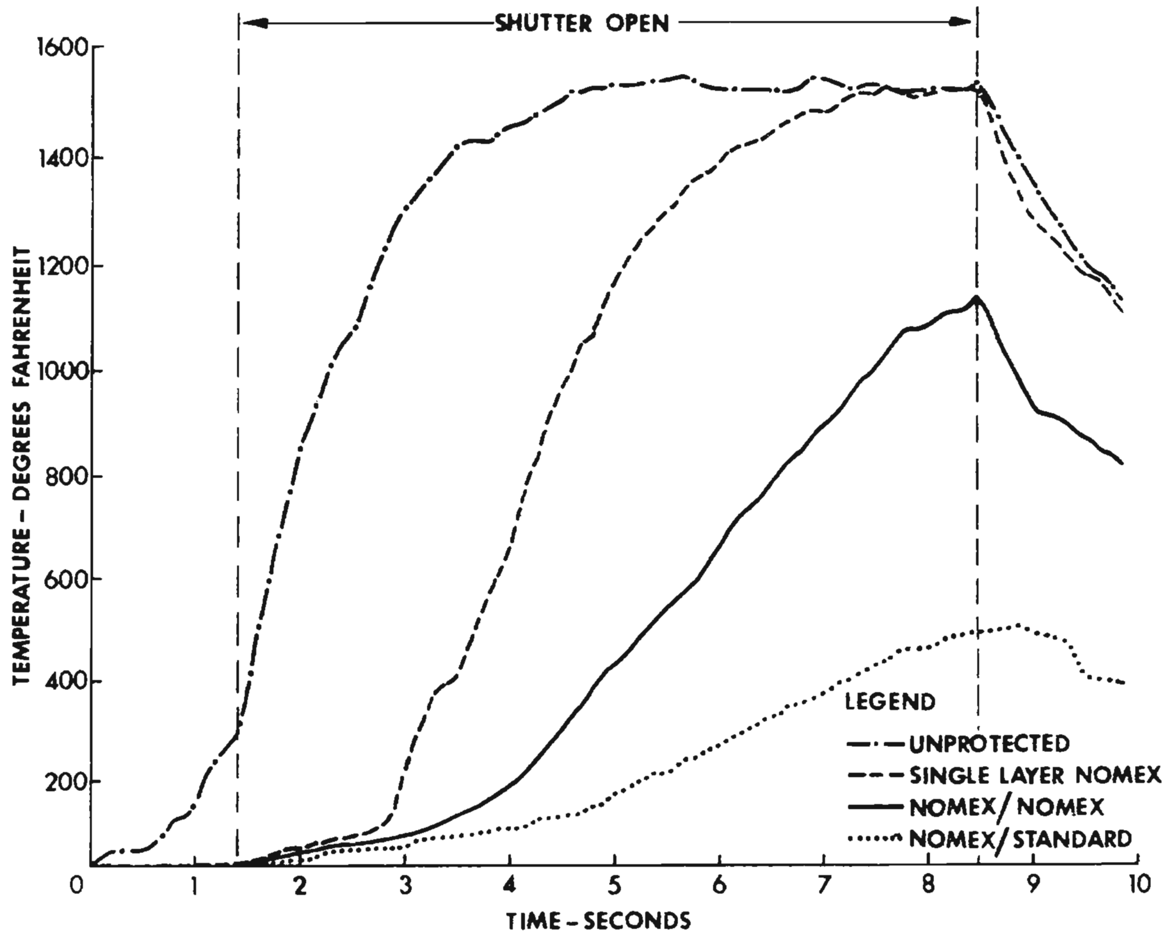


FIGURE 7. These representative temperatures were measured by a thermocouple placed between the fabric and the skin at the center of each test site. The temperature rise which occurred before the shutter opened is due to the heating of the shutter by the flame gun.



TIME - TEMPERATURE RELATIONSHIPS FOR A 20 SECOND BURN

FIGURE 8. These representative temperatures were measured by a thermocouple placed between the fabric and the skin at the center of each test site. The temperature rise which occurred before the shutter opened is due to the heating of the shutter by the flame gun.

TABLE III

DEGREE OF BURN ASSOCIATED WITH TIME-TEMPERATURE RELATIONSHIPS IN FIGURES 6, 7, 8

FABRIC	1.75 SEC		3.5 SEC		7.0 SEC	
	GROSS	MICRO	GROSS	MICRO	GROSS	MICRO
Unprotected	4.0	3.7	5.0	4.3	6.0	5.3
Nomex	2.7	3.3	4.0	4.0	5.0	4.7
Nomex/Nomex	0	0	1.0	2.7	4.3	5.0
Nomex/Standard	0	0	0.7	2.3	3.0	3.7

The following nine photographs show skin burns and damaged fabric samples. To assist the reader in viewing these figures, the following explanation is presented. Only the fabrics and skin areas located in the upper center, upper right, lower center, and lower right positions are the subject of this report. The data in the upper and lower, left positions belong to another study conducted concurrently with that reported here. The white objects protruding into the center of each template hole are the 0.005 inch chromel/alumel thermocouples used to record the temperature at the fabric-skin interface. The figures are arranged so the burn in the lower right position of Figure 9a corresponds to the fabric samples at the lower right position in Figures 9b and 9c.

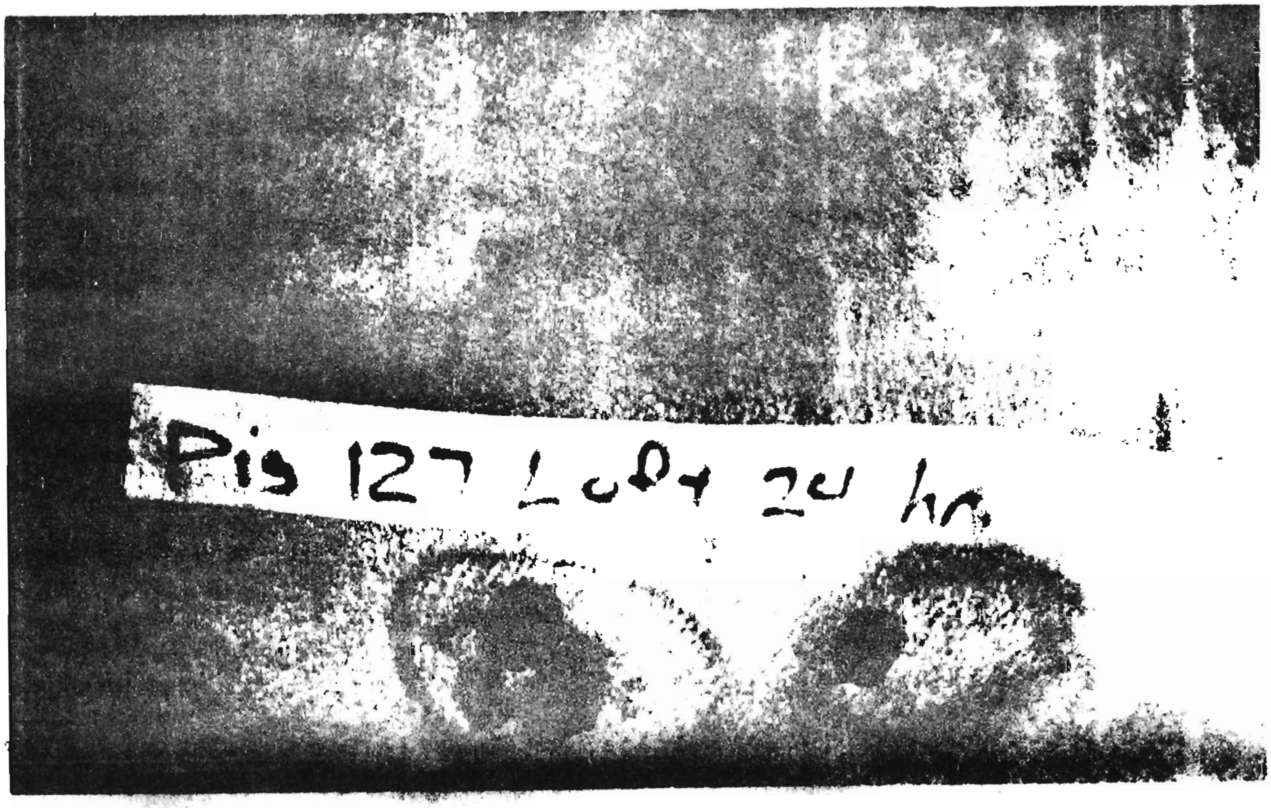


FIGURE 9a

FIGURE 9a. Porcine skin after a 1.75 second exposure.

FIGURE 9b. Front of wooden template after a 1.75 second exposure.

FIGURE 9c. Rear of wooden template after a 1.75 second exposure.

The upper center position was covered with Nomex over Nomex underwear and received no noticeable burn (0 level, gross evaluation).

The upper right position was covered with Nomex over Nomex underwear and received no noticeable burn (0 level, gross evaluation).

The lower center position was unprotected and received a 4.0 level burn (gross evaluation).

The lower right position was covered with a single layer of Nomex and received a 2.7 level burn (gross evaluation).

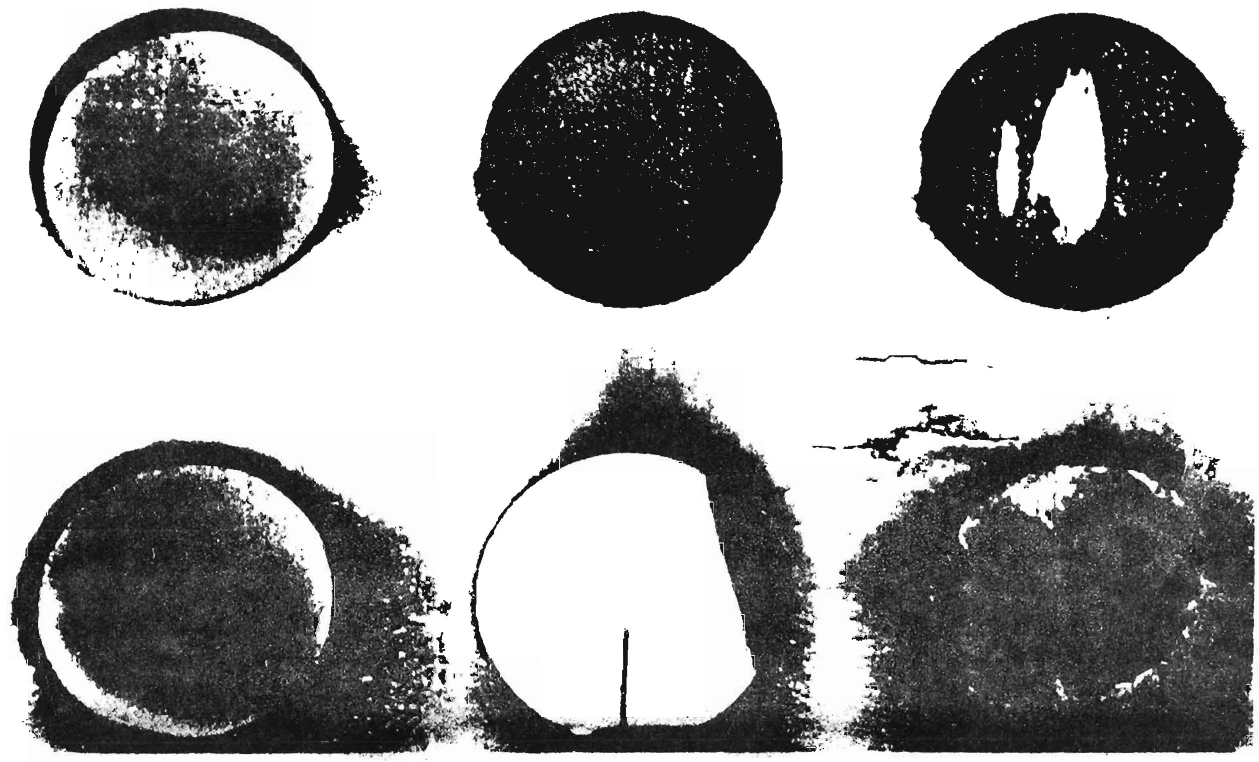


FIGURE 9b

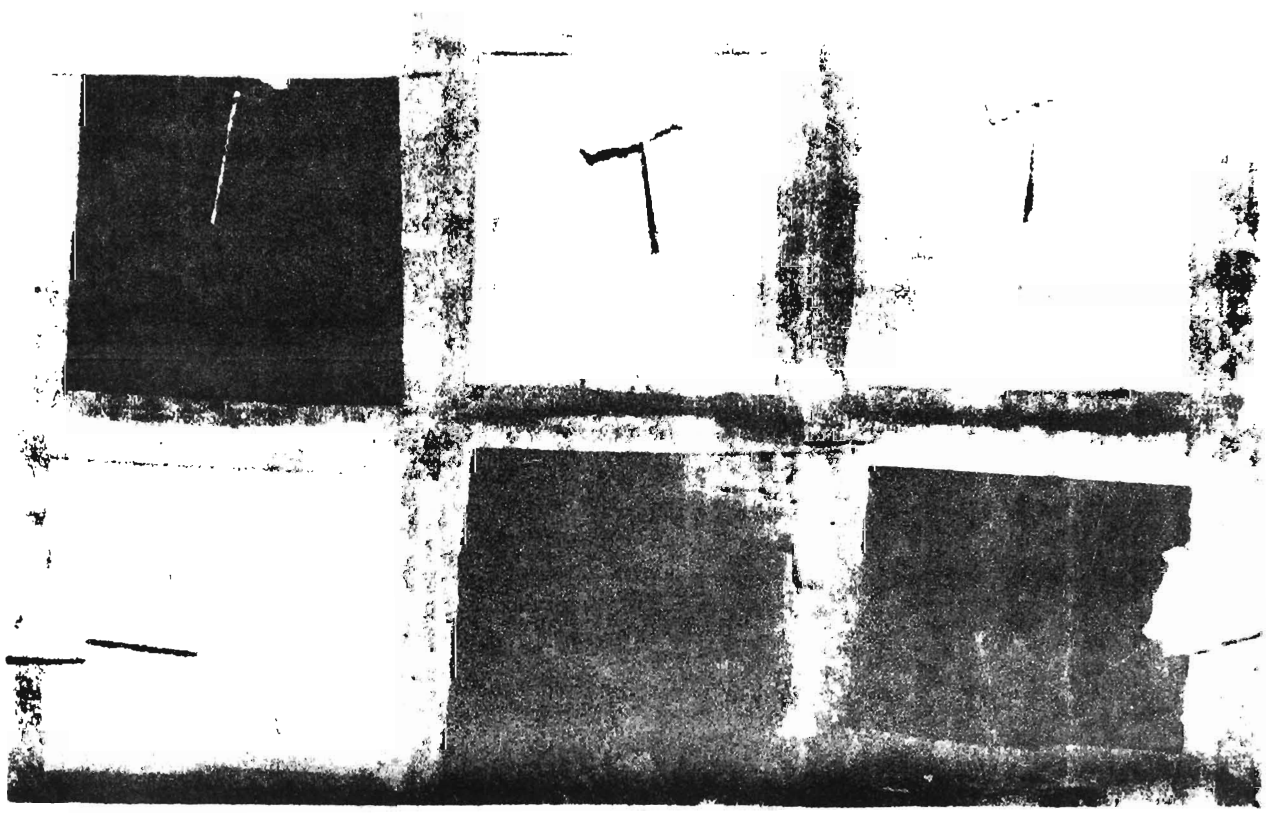


FIGURE 9c

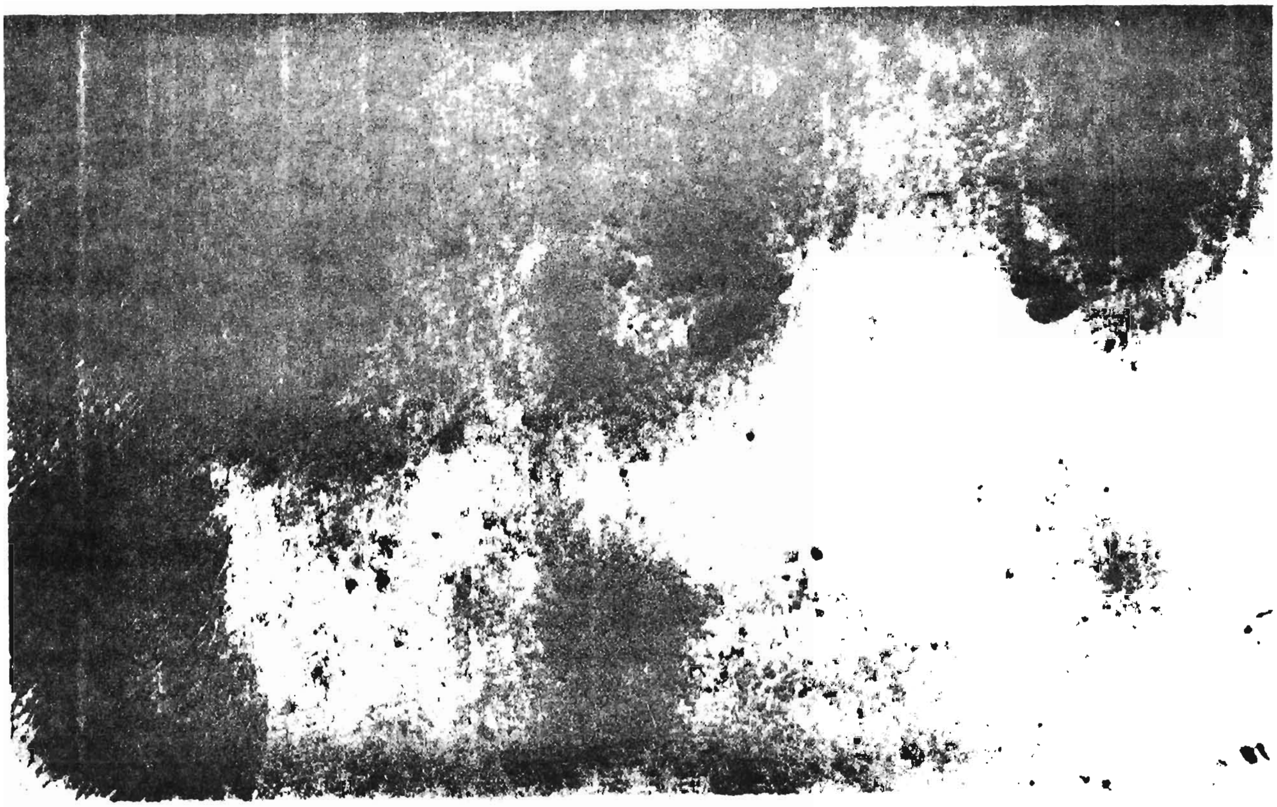


FIGURE 10a

FIGURE 10a. Porcine skin after a 3.5 second exposure.

FIGURE 10b. Front of wooden template after a 3.5 second exposure.

FIGURE 10c. Rear of wooden template after a 3.5 second exposure.

The upper center position was covered with a single layer of washed Nomex and received a 4.0 level burn (gross evaluation).

The upper right position was unprotected and received a 5.0 level burn (gross evaluation).

The lower center position was covered with Nomex over washed Nomex underwear and received a 1.0 level burn (gross evaluation).

The lower right position was covered with Nomex over washed standard underwear and received a 0.7 level burn (gross evaluation).

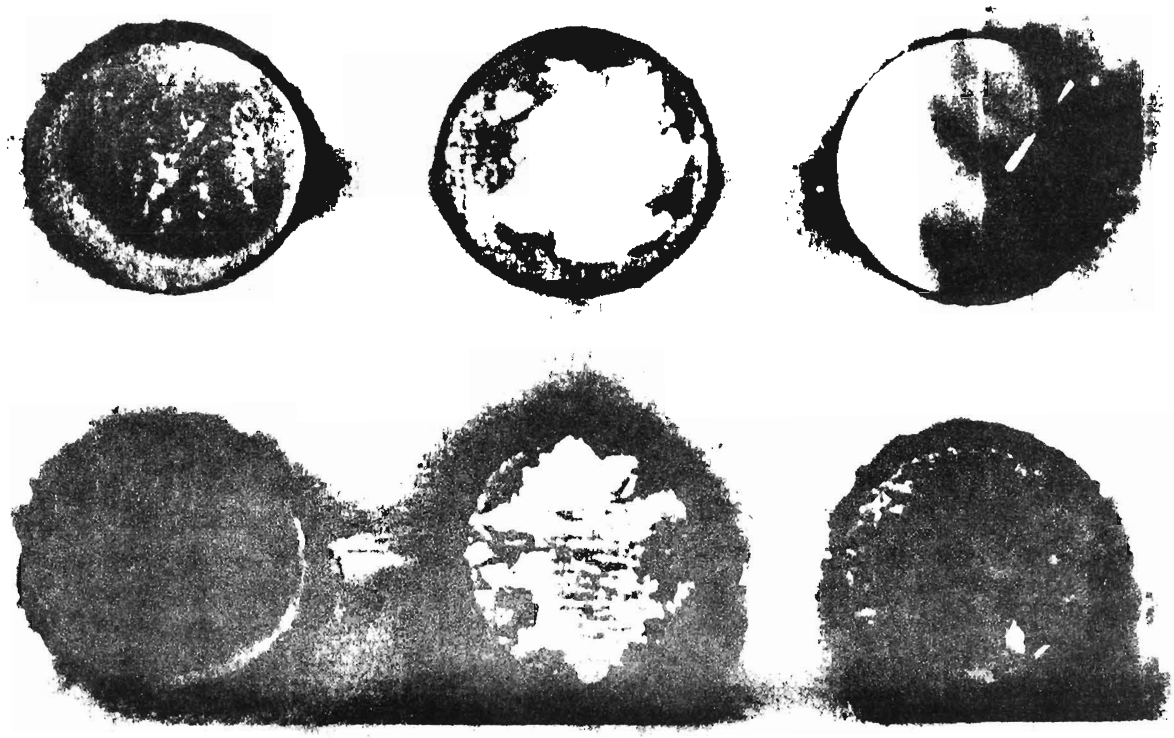


FIGURE 10b

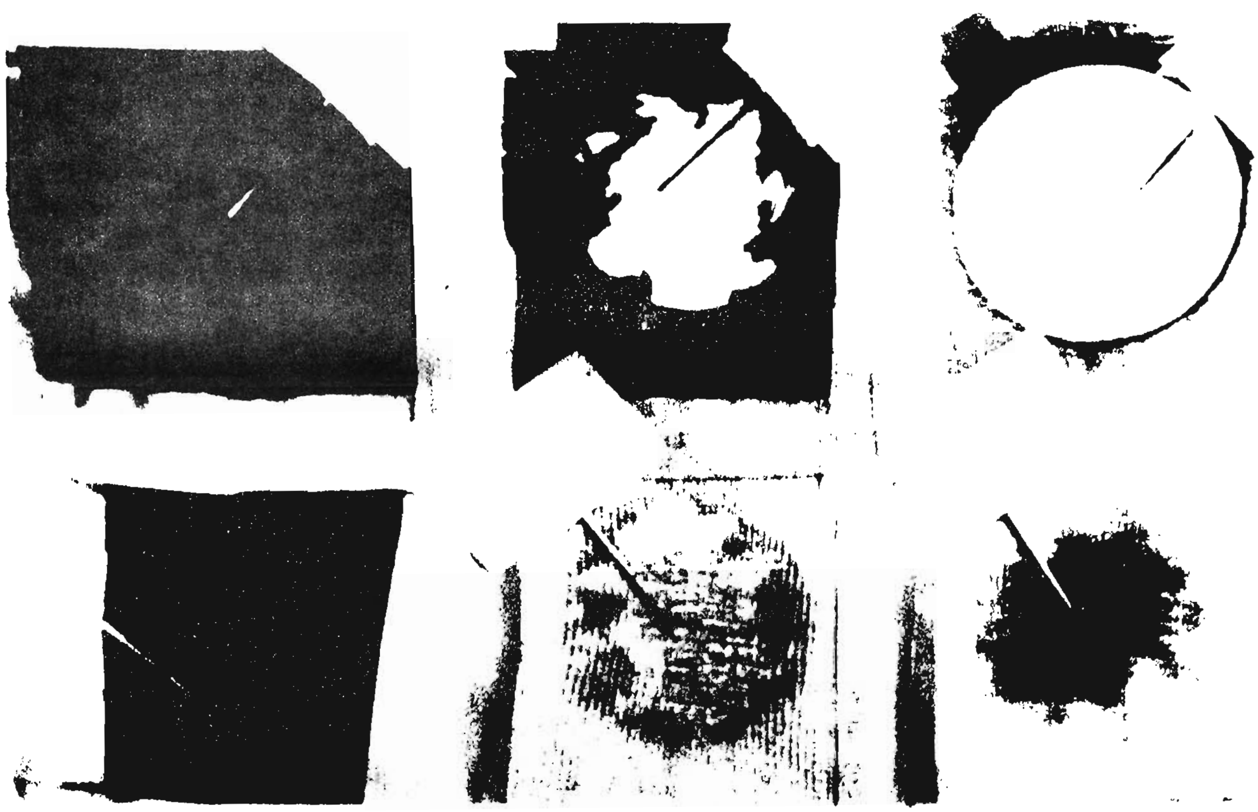


FIGURE 10c

FIGURE 11a

FIGURE 11a. Porcine skin after a 7.0 second exposure.

FIGURE 11b. Front of wooden template after a 7.0 second exposure.

FIGURE 11c. Rear of wooden template after a 7.0 second exposure.

The upper center position was covered with Nomex over washed Nomex underwear and received a 4.3 level burn (gross evaluation).

The upper right position was covered with Nomex over washed standard underwear and received a 3.0 level burn (gross evaluation).

The lower center position was covered with a single layer of washed Nomex and received a 5.0 level burn (gross evaluation).

The lower right position was unprotected and received a 6.0 level burn (gross evaluation).

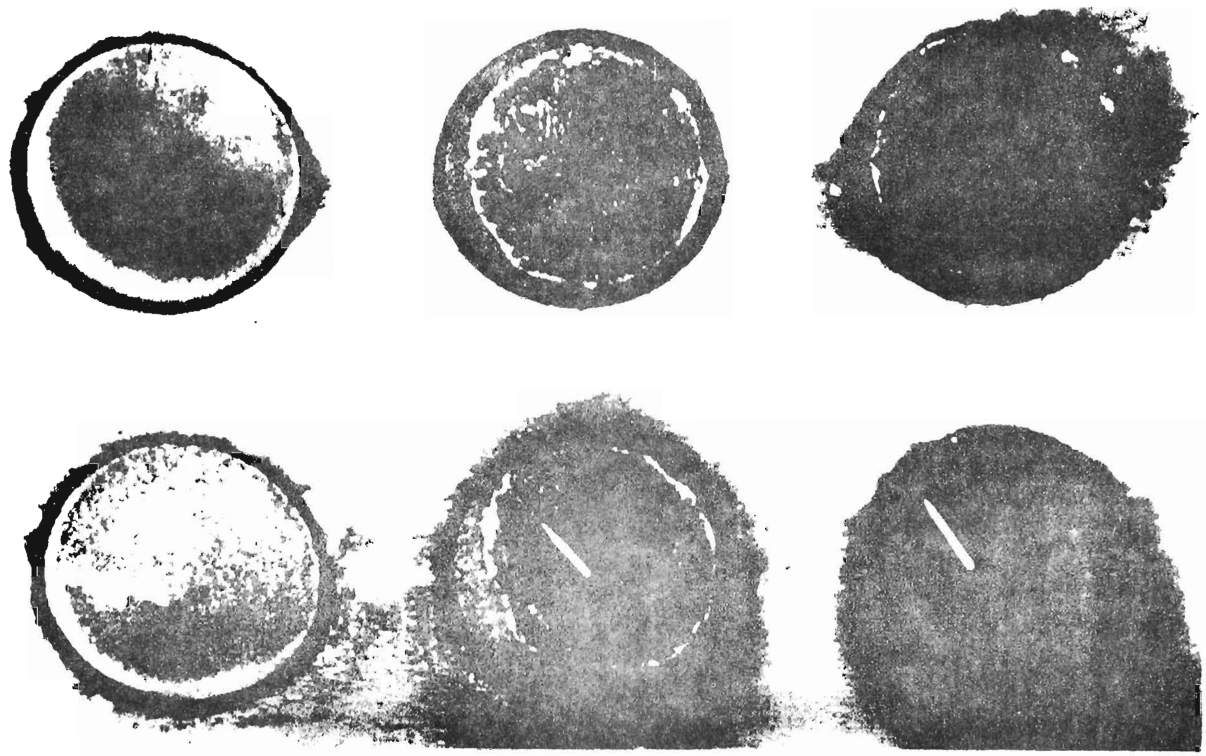


FIGURE 11b

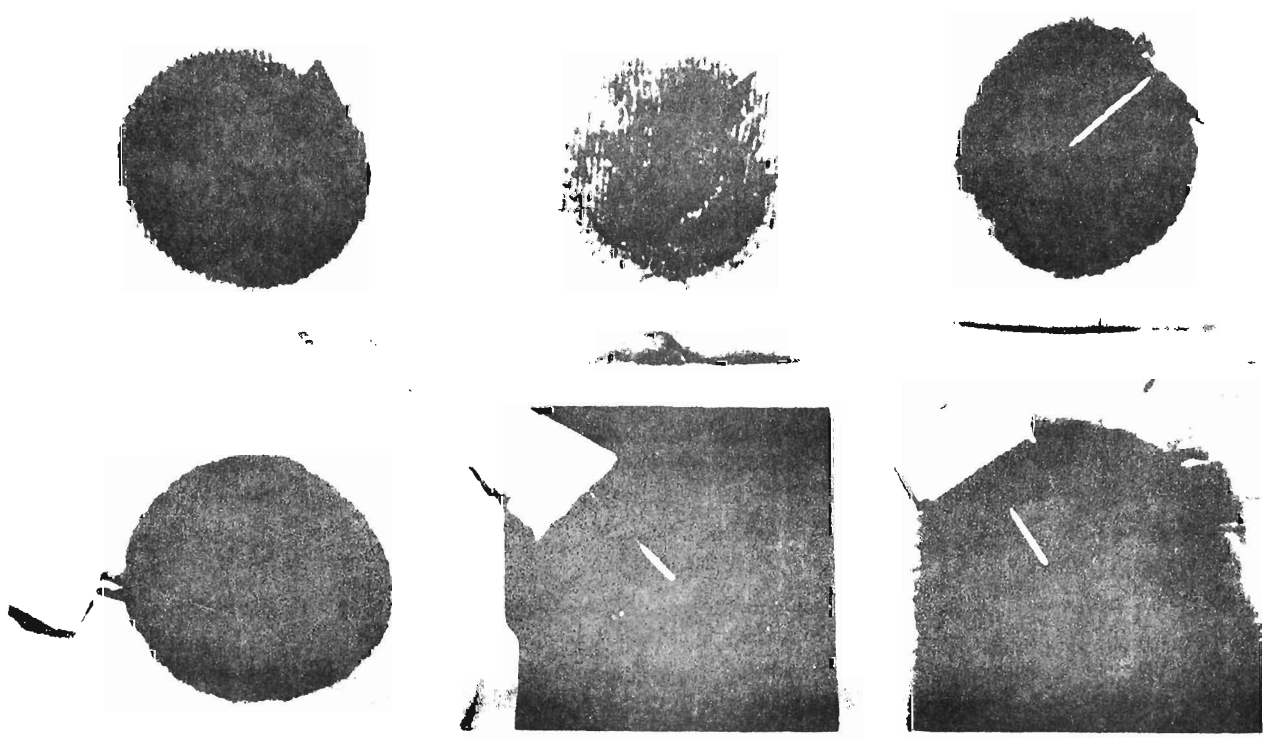


FIGURE 11c

DISCUSSION

The initial surface alteration on exposure to flame was a pink unstable lesion characterized by hyperemia. This disappeared by the 24 hour evaluation. A slightly more severe stage was a stable erythema or red burn. The next level of severity was a purple circulostasic state that generally receded to an erythematous burn (1+), or occasionally proceeded to the spotty red and greenish-yellow (in approximately equal amounts) patterns of patchy coagulation. The off-white (different from the usual white pig skin) color of uniform coagulation followed. The early appearance of "crumpled tissue paper" steam blebs marked the end of the white burn (3+). Steam blebs were gray, delicate, and broad-based with more severe burns beginning to show central or multifocal charred epithelium and hair stubble (4+). As the severity progressed the bleb was consumed, and charring spread peripherially until the entire test site became charred and cadaveric. Change in the pliability was only moderately noted even at the 24 hour evaluation. Any hair stubble could be easily removed. Some burn lesions appeared to be even more severely carbonized and were nonpliable in the immediate post-burn evaluation (6.0). In these no hair was present to be removed.

Although the less severe burns tended to improve slightly and the more severe burns tended to progress to a slightly worse grade from that observed in the immediate post-burn evaluation, all burn test sites failed to deviate after 24 hours thus making the surface appearance during the serial biopsies essentially unchanged.

The 5 cm test sites were sharply demarcated with very little edge effect at these short exposures to high intensity flame. They were circumscribed by a red ring (red burn) of not more than 2 mm in width. When the fabric or fabric combinations failed, several grades of burn could be identified within the same test site mimicking the fabric failure areas. The ceramic covered thermocouples offered some protection from the more severe burns; but because of their ability to retain heat, they frequently produced erythema and patchy or uniform coagulation in the least severe burns.

Microscopic examination of the skin specimens revealed damage ranging from none, in control biopsies, to almost fourth degree burn in unprotected 7.0 second exposures. The description of general pathology and classification of the burns were based on the works of Anderson(9) and Jobb and Kennedy.(10) According to these authors, burns are generally classified according to the depth of injury. As heat is absorbed, the epidermis is the first and most severely injured.

First degree burns are manifested by erythema and edema with no morphological sign of injury to the epithelial cells.

In second degree burns, the epidermis is destroyed without significant irreversible damage to the dermis. Vascular changes are prominent, and vesicles form in and beneath the epidermis. These may contain serum, cellular debris and leukocytes, and may suppurate or rupture quickly. The cytoplasm of the epithelial cells is coagulated and nuclei shrunken or ruptured.

Third degree burns show sufficient damage to the dermis, with coagulation and destruction of part of the connective tissue, blood vessels, and adnexa, to interfere with epithelial regeneration. Heat of sufficient intensity or duration to penetrate this deep usually desiccates and chars the outer epidermis. An amorphous agglomeration is produced by coagulation of the epidermis and dermis.

Fourth degree burns are similar in character to third degree, but penetrate below the dermis and through the subcutaneous fascia. The preceding criteria were used to judge the degree of burn to the skin specimens. When third degree burns were present, the depth and extent of injury to the dermis was determined. The numerical grades developed from these descriptive criteria were used to plot the data (Figure 5) and for statistical analyses.

Understanding that there is an apparent assymetry to the flame front (Table I), there are two questions that must be answered. (1) Are any of the positions significantly hotter than the others? (2) If so, then are the burns produced at the hotter locations discernably worse when all other parameters (duration of exposure, protection system, etc.) are held constant? The second question really asks if pig skin and our methods of burn analyses are sensitive enough to detect small differences in heat flux.

A one way analysis of variance showed that the effect of position on heat flux was highly significant (P=0.005). It was necessary, therefore, to take position into account in the analysis of our results.

A multiway analysis of variance was conducted with possible main effects listed as time of exposure, position, and type of material. A "t" test of unwashed vs washed materials had shown that except for marginal significance (P=0.1) for Nomex/Standard at 7.0 seconds, the effect of washing was not significant. Therefore, all data were collapsed across washing, ie, data from washed and unwashed materials were combined. This multiway analysis of variance revealed the following:

1. There was a significant time effect in the expected direction, ie, longer time leads to more severe burn.

2. There was significant fabric effect with double-layered systems providing better protection than single layers or none (Table IV).

3. No significant first or second order interactions were found.

4. No significant position effect existed.

The main effect due to type of fabric is summarized in Table IV using gross burn evaluation.

TABLE IV

DEGREE OF BURN (GROSS) COMPARED FOR DIFFERENT PROTECTIVE SYSTEMS

FABRIC	1.75 SEC n=10	3.5 SEC n=11	7.0 SEC n=12
O vs N	S	S	S
O vs N/N	S	S	S
O vs N/S	S	S	S
N vs N/N	S	S	S
N vs N/S	S	S	S
N/N vs N/S	-	X	X

O = Control, no protection
N = Single layer Nomex outer shell fabric
N/N = Nomex outer shell with Nomex underwear
N/S = Nomex outer shell with standard underwear
- = Not significant at P=0.1
X = Significant at P<0.05
S = Highly significant at $P \leq 0.005$

Table IV and Figure 4 show that any of the fabric systems evaluated provides some protection. The double-layered fabric systems evaluated were always superior to single-layered Nomex, and the system using standard underwear offered significantly more protection at 3.5 and 7.0 seconds. A close look at Figure 4 will indicate, however, that while these fabric systems do indeed offer some protection from burns when the flame source is set to deliver the equivalent heat flux of a well developed JP-4 fire,(6) ie, 14.0 BTU/ft^2/sec (3.78 cal/cm^2/sec), they do not, from the standpoint of survival, provide protection beyond some rather short time.

Table V summarizes comparisons between protective systems using the burn grades from the histopathologic studies. A multiway analysis of variance gave results similar to those for gross evaluations. (Table V)

TABLE V

DEGREE OF BURN (MICROSCOPIC) COMPARED FOR DIFFERENT PROTECTIVE SYSTEMS

FABRIC	1.75 SEC n=10	3.5 SEC n=11	7.0 SEC n=12
O vs N	-	M	-
O vs N/N	S	S	-
O vs N/NS	S	S	-
N vs N/N	S	S	M
N vs N/S	S	S	X
N/N vs N/S	-	-	-

M = Marginally significant at P=0.1
\- = Not significant at P=0.1
S = Highly significant at $P \leq 0.005$
X = Significant at $P \leq 0.05$

An analysis of the microscopic evaluation of the tissue specimens reveals that protection by single-layered Nomex is marginal or not significant and that double layers N/N and N/S) protect better (P=0.005) than either Nomex or no protection. At 7.0 seconds no real protection is afforded by any system since all systems experienced third degree (4.0) burns.

These results (microscopic evaluation) are accompanied by a possible source of error. In looking at the results, there are cases, where the grade given an unprotected hole is lower than an adjacent hole protected by Nomex which received a severe burn. In these cases the gross evaluation was in the expected direction (unprotected, severe; Nomex, less severe). This discrepancy can be accounted for if the biopsy was taken from a typical part of the burned area. In most cases these inconsistencies could be checked by consulting the photographs and medical illustrations.

There is no satisfactory way to correct for these apparent errors, without jeopardizing the independence of the microscopic evaluation. Therefore, the results are presented, as recorded, without any attempt to scale or "correct" the data. Subjectively, the gross evaluations appear to give more consistent data because any apparent errors can be checked with the photographs and drawings of the burns without prejudicing the evaluation.

The conclusions drawn from this experiment are tempered by the degree to which the gross and microscopic evaluations do not agree. From Figures 4 and 5, however, it is clear that the disagreement is not severe.

The time temperature data (Figures 6, 7, 8) indicate that the total tissue (skin) damage is related to the area under the time-temperature curve as pointed out by Stoll.(11) It should be noted that the recorded temperatures are the temperatures of the cloth-skin interface and not necessarily the temperatures of the surface of the skin.

The initial rise in the temperature of unprotected skin (Figures 6, 7, 8) is due to preheating by radiation from the hot shutter. This moderate preheating may affect the performance of a given fabric, but since the temperatures are well below the "melting" temperatures of the fabrics, the effect is probably minimal.

The inflection point occurring between 0.8-1.4 seconds in single-layered Nomex curves reflects fabric break-through. On some curves for the double-layered systems, it is possible to see two inflections, one for the outer layer and one for the underwear.

It is clear that the air-skin interface reaches a steady-state temperature (unprotected and single-layered Nomex) within 7.0 seconds. (Figure 8) For the unprotected or control site this exposure results in a maximum level burn, ie, 6.0 on the gross evaluation scale.

There are three main factors that interact to determine the survivability of an aviator exposed to a post-crash fire. First, there is the thermal environment to which he is exposed. Of course, this environment varies from accident to accident. Usually there will be some short period of time during which the fire is developing into the severe thermal environment represented by the flame gun in this test. This period of warm-up acts to increase the survival time of the aviator against the case when a fire reaches "worst-credible-proportions" instanteously.

Second, the fit of the uniform determines the degree to which a given fabric will transfer heat and cause burns. This study addressed only the case in which the fabric is closely applied to the skin, and by so doing skewed the results toward more severe burns. Less severe burns would have been observed if an air space existed between the pig and the fabric to represent a loose fitting garment. The method of application in this experiment was chosen to provide consistent data and to represent the normal garment fit in the areas of knees, elbows, shoulders, and buttocks. Our method even more closely models the garment as worn by aviatiors who have gained weight or wear smaller uniforms to look more "military".

Third, there are well known correlations among age, sex, and general health to severity and area of burn.(3,12) The usual rating systems weight second degree burns one-third to one-half as traumatic as third degree burns; but difficulties in accurately judging the depth of burn in the clinical situation have led to survivability tables that relate area of total burn (second and third degree) to survivability within specified age groups.(3,12)

To show how the winter flight suit might protect the aviator we present the following example. Assume that aviators are male, healthy, between the ages of 20 and 50, and receive no more than 40% of total body area burn (second and third degree) in a worst-credible environment (well developed JP-4 fire). The time of exposure for each protective system giving rise to a severe second degree burn (level 3.0, Figures 4 and 5) using our data, is summarized in Table VI.

TABLE VI

TIME TO REACH SEVERE SECOND DEGREE BURN

FABRIC	TIME (SEC) GROSS (FIG 4)	MICRO (FIG 5)
O	1.2	1.3
N	1.8	1.45
N/N	5.7	5.6
N/S	6.4	6.2

The mortality of aviators between the ages of 20 and 52 having received such a burn is summarized in Table VII.

TABLE VII

MORTALITY (ADAPTED FROM REF 3)
(Assuming: Male, healthy, 40% area second and third degree burns and adequate medical care)

AGE	PROBABILITY OF DEATH
20	0.23
24	0.19
28	0.21
32	0.24
36	0.30
40	0.37
44	0.45
48	0.52
52	0.61

These predictions assume that the aviator received adequate medical care promptly. The survivability decreases if there is delay in stabilizing the patient and taking him to an adequate treatment center.

CONCLUSIONS

1. None of the fabric systems evaluated meet the essential requirement (10 seconds protection) for Army aviator's flight clothing.

2. Single layered fabric systems offer slight protection.

3. Double layered systems evaluated offer more than three times the protection of single layers but fail to provide 10 seconds of protection.

4. Standard underwear worn under a standard Nomex outer shell provides equal or better protection than the experimental Nomex underwear worn under a standard Nomex outer shell.

5. Washing does not affect thermal protection.

6. Our method using pigs provides a very consistent and meaningful way of evaluating thermal protective fabrics.

REFERENCES

1. Zilioli, Armand E., USAARL Report No. 71-17, "Crash Injury Economics: The Costs of Training and Maintaining an Army Aviator", Fort Rucker, Alabama, April 1971.

2. Zilioli, Armand E., USAARL Report No. 71-18, "Crash Injury Economics: Aircrewman Injury and Death Costs Ocurring in UH-1 Army Aircraft Accidents in Fiscal Year 1969", Fort Rucker, Alabama, June 1971.

3. McCoy, J.A.; Micks, D.W.; and Lynch, J.B.; "Discriminant Function Probability Model for Predicting Survival in Burned Patients", JAMA 203:644-6, 1968.

4. Department of the Army Approved Small Development Requirement (SDR) for Clothing System for Army Aircrewmembers, Par 26(2), 9 February 1966.

5. Hinshaw, J. Raymond; Payne, Fred W.; "The Restoration and Remodeling of the Skin After a Second Degree Burn", Surg-Gynec. Obstet. 117:738-744, 1963.

6. Albright, John D.; Knox, Francis S.,III; DuBois, David R.; and Keiser, George M.; USAARL Report No. 71-24, "The Testing of Thermal Protective Clothing in a Reproducible Fuel Fire Environment, A Feasibility Study", June 1971.

7. Perkins, J.B.; Pearse, H.E.; and Kingsley, H.D.; "Studies on Flash Burns", University of Rochester, Atomic Energy Project Report, UR-217, 1952.

8. AFIP Manual of Histologic and Special Staining Technique, 2nd Edition, New York, Blackstone Division of McGraw Hill Book Company.

9. Anderson, W.A.D., Pathology, 5th Edition, Volume 1, St. Louis, The C.V. Mosby Company, 1966.

10. Jobb, K.Y.F. and Kennedy, P.C., Pathology of Domestic Animals, 2nd Edition, Volume 2, New York, Academic Press, 1970.

11. Stoll, Alice M., "Thermal Protection Capacity of Aviator's Textiles", Aerospace Medicine, pp. 846-850, June 1962.

12. Artz, Curtis P., and Moncrief, John A., The Treatment of Burns, pp. 89-108, 2nd Edition, Philadelphia, W.B. Saunders Company, 1969.

LIST OF EQUIPMENT

VETERINARY

1. Heidbrink Model 970 - Veterinary Anesthesia Unit
2. CAP-CHUR Equipment (Palmer Chemical and Equipment Company)
3. Drugs
   a. Sernylan (phencylidine hydrochloride - Parke-Davis)
   b. Thorazine (chlorpromazine - Pitman-Moore)
   c. Penthrane (methoxyflurane - Abbot)
   d. Atropine Sulfate

EXPERIMENTAL APPARATUS

1. Flame gun - Conversion oil burner, modified Lennox, Model OB-32, loaned by the National Aviation Flight Engineering Center, NAFEC, Atlantic City, New Jersey.
2. Fuel - Kerosene

DATA ACQUISITION

1. HyCal, Model C1300 water cooled calorimeters
2. Omega, 0.005 inch and 0.032 inch unshielded, chromel alumel thermocouples
3. Technirite, Model TR-888 strip chart recorder.
4. Consolidated Electrodynamics, Model 5-124 recording oscillograph
5. Non-Linear Systems, DART LX-2 digital multimeter
6. Standard SW-1 Timer
7. GraLab Universal, 60 minute, Electric timer

ARL 71-19 AD

US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION by Francis S. Knox, III, George R. McCahan, Jr., Thomas L. Wachtel, Walter P. Trevethan, Andrew S. Martin, David R. DuBois, George M. Keiser, 33 pp, DA Project 3A0 6211 OA 819, Bioengineering & Evaluation Division.

UNCLASSIFIED

1. Burns
2. Thermal Protective Clothing
3. Test Methods
4. Laboratory Animals
5. Life Support Equipment
6. Aviation Safety

This report describes the use of a bioassay technique to evaluate the fire resistant and thermal protection capabilities of the lightweight underwear of the Army winter flight clothing system. Samples of fabrics under consideration for inclusion in the Army winter flight clothing system were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a flame source calibrated to simulate a well developed JP-4 fire. Exposure times of 1.75, 3.50, and 7.0 seconds were used. Evaluation of resultant skin burns shows that none of the fabric systems, as evaluated, meet the essential requirement of 10 seconds protection. Single-layered fabric (Nomex shell fabric) offers slight protection and double-layered fabric systems (Nomex outer shell with either Nomex underwear or 50% cotton/50% wool underwear) offer more than three times the protection of single layers, but still fail to provide 10 seconds of protection. The 50% cotton/50% wool underwear offers equal or better protection than experimental Nomex underwear worn under standard Nomex outer shell. Washing does not affect thermal protection. The data further indicate that the method using pigs provides a very consistent and meaningful way of evaluating thermal protective fabrics.

FT RUCKER 101087

ARL 71-19 AD

US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION by Francis S. Knox, III, George R. McCahan, Jr., Thomas L. Wachtel, Walter P. Trevethan, Andrew S. Martin, David R. DuBois, George M. Keiser, 33 pp, DA Project 3A0 6211 OA 819, Bioengineering & Evaluation Division.

UNCLASSIFIED

1. Burns
2. Thermal Protective Clothing
3. Test Methods
4. Laboratory Animals
5. Life Support Equipment
6. Aviation Safety

This report describes the use of a bioassay technique to evaluate the fire resistant and thermal protection capabilities of the lightweight underwear of the Army winter flight clothing system. Samples of fabrics under consideration for inclusion in the Army winter flight clothing system were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a flame source calibrated to simulate a well developed JP-4 fire. Exposure times of 1.75, 3.50, and 7.0 seconds were used. Evaluation of resultant skin burns shows that none of the fabric systems, as evaluated, meet the essential requirement of 10 seconds protection. Single-layered fabric (Nomex shell fabric) offers slight protection and double-layered fabric systems (Nomex outer shell with either Nomex underwear or 50% cotton/50% wool underwear) offer more than three times the protection of single layers, but still fail to provide 10 seconds of protection. The 50% cotton/50% wool underwear offers equal or better protection than experimental Nomex underwear worn under standard Nomex outer shell. Washing does not affect thermal protection. The data further indicate that the method using pigs provides a very consistent and meaningful way of evaluating thermal protective fabrics.

FT RUCKER 101087

ARL 71-19 AD

US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION by Francis S. Knox, III, George R. McCahan, Jr., Thomas L. Wachtel, Walter P. Trevethan, Andrew S. Martin, David R. DuBois, George M. Keiser, 33 pp, DA Project 3A0 6211 OA 819, Bioengineering & Evaluation Division.

UNCLASSIFIED

1. Burns
2. Thermal Protective Clothing
3. Test Methods
4. Laboratory Animals
5. Life Support Equipment
6. Aviation Safety

This report describes the use of a bioassay technique to evaluate the fire resistant and thermal protection capabilities of the lightweight underwear of the Army winter flight clothing system. Samples of fabrics under consideration for inclusion in the Army winter flight clothing system were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a flame source calibrated to simulate a well developed JP-4 fire. Exposure times of 1.75, 3.50, and 7.0 seconds were used. Evaluation of resultant skin burns shows that none of the fabric systems, as evaluated, meet the essential requirement of 10 seconds protection. Single-layered fabric (Nomex shell fabric) offers slight protection and double-layered fabric systems (Nomex outer shell with either Nomex underwear or 50% cotton/50% wool underwear) offer more than three times the protection of single layers, but still fail to provide 10 seconds of protection. The 50% cotton/50% wool underwear offers equal or better protection than experimental Nomex underwear worn under standard Nomex outer shell. Washing does not affect thermal protection. The data further indicate that the method using pigs provides a very consistent and meaningful way of evaluating thermal protective fabrics.

FT RUCKER 101087

ARL 71-19 AD

US Army Aeromedical Research Laboratory, Fort Rucker, Alabama, ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION by Francis S. Knox, III, George R. McCahan, Jr., Thomas L. Wachtel, Walter P. Trevethan, Andrew S. Martin, David R. DuBois, George M. Keiser, 33 pp, DA Project 3A0 6211 OA 819, Bioengineering & Evaluation Division.

UNCLASSIFIED

1. Burns
2. Thermal Protective Clothing
3. Test Methods
4. Laboratory Animals
5. Life Support Equipment
6. Aviation Safety

This report describes the use of a bioassay technique to evaluate the fire resistant and thermal protection capabilities of the lightweight underwear of the Army winter flight clothing system. Samples of fabrics under consideration for inclusion in the Army winter flight clothing system were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a flame source calibrated to simulate a well developed JP-4 fire. Exposure times of 1.75, 3.50, and 7.0 seconds were used. Evaluation of resultant skin burns shows that none of the fabric systems, as evaluated, meet the essential requirement of 10 seconds protection. Single-layered fabric (Nomex shell fabric) offers slight protection and double-layered fabric systems (Nomex outer shell with either Nomex underwear or 50% cotton/50% wool underwear) offer more than three times the protection of single layers, but still fail to provide 10 seconds of protection. The 50% cotton/50% wool underwear offers equal or better protection than experimental Nomex underwear worn under standard Nomex outer shell. Washing does not affect thermal protection. The data further indicate that the method using pigs provides a very consistent and meaningful way of evaluating thermal protective fabrics.

FT RUCKER 101087

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) US Army Aeromedical Research Laboratory Fort Rucker, Alabama	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
Engineering Test of Lightweight Underwear of the Winter Flight Clothing System: Thermal Protection

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Paper for publication

5. AUTHOR(S) (First name, middle initial, last name)
Francis S. Knox, III; Walter P. Trevethan; George M. Keiser; George R. McCahan, Jr.; Andrew S. Martin; Thomas L. Wachtel; David R. DuBois

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1971	33	12

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 3AO 6211 OA 819 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 71-19 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
This document has been approved for public release and sale; its distribution is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	US Army Medical R&D Command Washington, D.C. 20314

13. ABSTRACT

This report describes the use of a bioassay technique to evaluate the fire resistant and thermal protection capabilities of the lightweight underwear of the Army winter flight clothing system. Samples of fabrics under consideration for inclusion in the Army winter flight clothing system were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a flame source calibrated to simulate a well developed JP-4 fire. Exposure times of 1.75, 3.50, and 7.0 seconds were used.

Evaluation of resultant skin burns shows that none of the fabric systems, as evaluated, meet the essential requirement of 10 seconds protection. Single layered fabric (Nomex shell fabric) offers slight protection and double layered fabric systems (Nomex outer shell with either Nomex underwear or 50% cotton/50% wool underwear) offer more than three times the protection of single layers, but still fail to provide 10 seconds of protection. The 50% cotton/50% wool underwear offers equal or better protection than experimental Nomex underwear worn under standard Nomex outer shell. Washing does not affect thermal protection. The data further indicate that the method using pigs provides a very consistent and meaningful way of evaluating thermal protective fabrics.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Burns Thermal Protective Clothing Test Methods Skin Life Support Equipment Aviation Safety						

Unclassified
Security Classification

APPENDIX II FINDINGS

Item	Source	Requirements	Applicable Subtest	Remarks
1	USATECOM Approved Test Plan	Each experimental and standard underwear item will be indelibly marked for test control	2.1	MET. See par 2.1.5.
2	USATECOM Approved Test Plan	Each experimental and standard underwear item entering subsequent testing must be free from apparent material, manufacturing, or functional defects.	2.1	MET. See par 2.1.5
3	MIL-U-43262A	The experimental undershirts must meet the weight and finished measurements established for the standard undershirt in Table V, MIL-U-43262A.	2.2	MET. See par 2.2.5 and App I-A
4	MIL-D-43261A	The experimental drawers must meet the weight and finished measurements established for the standard drawers in Table VI, MIL-D-43261A.	2.2	MET. See par 2.2.5 and App I-A
5	TC to SDR par 2b(2)	"The clothing for Army Aviation Crewmembers will cover 95% of the skin area and be made of a material which will be flame resistant (i.e., when subjected to contact with flame will not continue to burn when the flame source is removed). This requirement is determined by Method 5903 of CCC-T-191 in which the after flame and char length requirements measure the tendency of the material to flame after removal of a flame source".	2.3	MET. See par 2.3.5 and Table I in App I-B

Note: The underlined portions of listed requirements are not applicable to this test.

APPENDIX II

Item	Source	Requirements	Applicable Subtest	Remarks
6	USATECOM Approved Test Plan	No fabric or fiber components of the experimental underwear will exhibit lower thermal degradation properties than the basic body fabric.	2.3	Not MET. See par 2.3.5b and Table II in App I-B
7	Textiles Series Report No. 110 USALABS, Sep 1959	The surface resistivity of new and laundered experimental underwear body fabric will not be less than 3.2 x 10^{12} ohms per square ~~unit~~ inch. ~~(Resistivities exceeding 3.2 x 10^{12} ohms are industrially classified as Poor to Satisfactory)~~. (Resistivities . . . as poor to unsatisfactory).	2.3	Not MET. See par 2.3.5c and 2.8.5; and Table III in App I-B
8	MIL-D-43261A MIL-U-43262A	The experimental underwear shall not shrink more than 8.0 percent throughout 20 launderings.	2.3	MET. See par 2.3.5d
9	SDR par 2c(1)	SDR par 2c(1) "(ESSENTIAL) The winter clothing system should protect the wearer and be designed for use under the climatic conditions contained in AR 70-38, with the exception that the cold weather protection of the basic uniform will be that which will be required in a 40°F cockpit temperature environment. Supplementary clothing protection shall be available for cold weather Categories 6, 7, and 8 as defined in AR 70-38".	2.4	MET. See par 2.4.5 and App I-C

APPENDIX II

Item	Source	Requirements	Applicable Subtest	Remarks
10	SDR par 2b(2)	"Features which are essential to all components of these uniforms are: (a) (ESSENTIAL) All components must be fire-retardant to a degree which will provide for protection from high intensity flash or flame for 10 seconds duration. This degree of protection must last for the life of the garment".	2.5	Not MET. See USAARL Report No. 71-19, App I-E
11	USAMC Supplement 1 to AR 11-26	The experimental items will have no unnecessary, costly, or nice-to-have features.	2.6	MET See par 2.6.5
12	USAMC Reg 385-12	The experimental underwear will impose no unusual hazard to the wearer.	2.7	MET. See par 2.7.5
13	USATECOM Reg 385-8	All personnel, whose activity relates to this testing, will be adequately indoctrinated and supervised in safety practices.	2.7	MET. See par 2.7.5
14	USATECOM Approved Test Plan	The electrostatic charge, accumulated on test personnel in combination with appropriate additive environmental clothing, will not exceed 500 volts of 0°F.	2.8	Not MET. 500 volts is considered maximum allowable at 40°F as well as 0°F (See par 2.85 and App I-D).

APPENDIX III. DEFICIENCIES AND SHORTCOMINGS

1. Deficiencies

Deficiency	Suggested Corrective Action	Remarks
1.1 Surface resistivity of experimental underwear exceeded criteria.	Aviation Test Board, as a result of ST, suggested anti-static treated materials be used (EPR KF-1-53).	Chemically treated experimental underwear (13 sets) was provided and subjected to electrostatic testing (Par 2.8). See 1.3 below. Resistivity performance was not improved.
1.2 Both experimental underwears failed to meet thermal protection criteria.	None	See App I-E, USAARL Report No. 71-19
1.3 All underwear systems failed to meet electrostatic characteristics criterion. (Par 2.8.5)	None	Since all systems failed, the specified criterion should be re-evaluated for validity (Par 2.8.5).

2. Shortcomings

Shortcomings	Suggested Corrective Action	Remarks
2.1 DTA results showed some deviations from criteria.	Use different material for components exceeding the criteria requirements.	See Table II in App I-B.

APPENDIX IV. ABBREVIATIONS

AATCC	American Association of Textile Chemist and Colorists
$BTU/ft^2/sec$	Britist Termal Unit per square foot per second
^oC	Degrees, Centrigrade
DTA	Differential Thermal Analysis
ET	Engineering Test
Exp	Experimental
^oF	Degrees, Fahrenheit
FAA	Federal Aviation Authority
FTMS	Federal Test Method Standard
HTRN	High temperature resistant nylon
L	Large
M	Medium
NAFEC	National Aviation Facilities Experimental Center
NCOIC	Noncommissioned Officer in Charge
RH	Relative humidity
RDTE	Research, Development, Test, and Evaluation
S	Small
SDR	Small Development Requirement
TC	Technical Characteristics
USAMC	U.S. Army Materiel Command
USAARL	U.S. Army Aeromedical Research Laboratory
USACDC	U.S. Army Combat Development Command
USAGETA	U.S. Army General Equipment Test Activity
USANLABS	U.S. Army Natick Laboratories
USATECOM	U.S. Army Test and Evaluation Command
VDC	Volts, direct current
X	Extra

APPENDIX V. REFERENCES

1. Letter, AMSTE-BG, USATECOM, 12 October 1970, subject: Test Directive, Engineering and Service Test, Lightweight Underwear of Winter Flight Clothing System, USATECOM Project No. 4-EI-485-AAC-007/008.

2. Letter, AMSTE-BG, USATECOM, 21 October 1970, subject: Medical Test Support, Engineering Test of Lightweight Underwear of Winter Flight Clothing System, USATECOM Project No. 4-EI-485-AAC-008.

3. Department of the Army Approval Small Development Requirement(SDR) for Clothing System for Army Aviation Crewmembers, 9 January 1966.

4. Technical Characteristics for Clothing System for Army Aviation Crewmembers, April 1966.

5. Technical Manual TM 10-354, Army Fixed Laundry Organization, August 1965.

6. Specification MIL-D-43261A, 12 November 1968, Military Specification, Drawers, Men's, Winter, Lightweight, with Amendment 2, 24 February 1970.

7. Specification MIL-U-43262 A, 20 January 1969, Military Specification, Undershirts, Men's, Winter, Lightweight, with Amendment 1, 6 October 1969.

8. Federal Test Method Standard No. 191, 31 December 1968, Textile Test Methods.

9. USATECOM Regulation 385-6, Safety, 6 May 1969.

10. Letter AMSTE-BG, USATECOM, 24 November 70, subject: Department of the Army Approved Small Development Requirement (SDR) for Clothing System for Army Aviation Crewmembers.

11. Army Regulation 70-38, Research Development, Test, and Evaluation of Material for Extreme Climatic Conditions, 5 May 1969.

12. Letter, AMSTE-BG, USATECOM, 8 March 1971, subject: Amendment to Test Directive, Engineering Test of Aviation Underwear, USATECOM Project No. 4-EI-485-AAC-008.

13. Report AAL-TDR-63-12 Accumulation of Static Electricity on Arctic Clothing, Arctic Aeromedical Laboratory, May 1963.

14. Test Plan, USATECOM Project No. 4-EI-485-AAC-008, Engineering Test of Lightweight Underwear of Winter Flight Clothing System, USAGETA, December 1970.

APPENDIX V

15. Letter, STEGE-MT-EC, USAGETA, 11 May 1971, subject; Change To Test Plan of Engineering Test of Lightweight Underwear of Winter Flight Clothing System.

16. Letter STEGE-MT-EC, USAGETA, 12 February 1971, subject: Change To Test Plan of Engineering Test of Winter Flight Clothing System.

APPENDIX VI. DISTRIBUTION LIST

USATECOM PROJECT NO. 4-EI-485-AAC-008

Agency	Final Reports
Commanding General U. S. Army Test and Evaluation Command ATTN: AMSTE-BG Aberdeen Proving Ground, Maryland 21005	40
Commanding General U. S. Army Materiel Command	
ATTN: AMCRD-JI	3*
AMCRD-U	1
AMCRD-R	1
AMCMA	1
AMCQA-P	1
AMCSF	1
Washington, D. C. 20315	
Commanding General U. S. Army Combat Developments Command ATTN: USACDC LnO, USATECOM Aberdeen Proving Ground, Maryland 21005	23*
U. S. Marine Corps LnO Headquarters, U. S. Army Test and Evaluation Command Aberdeen Proving Ground, Maryland 21005	1
Commanding General U. S. Army Natick Laboratories ATTN: AMXRE-CCE Natick, Massachusetts 01760	5*
Commanding General U. S. Continental Army Command ATTN: ATIT-RD-MD Fort Monroe, Virginia 22060	6*
Commanding Officer U. S. Army Logistics, Doctrine, Systems and Readiness Agency ATTN: LDSRA-ME New Cumberland Army Depot, P.O. Box 2947 Harrisburg, Pennsylvania 17105	1*

*Copies furnished by Headquarters, USATECOM.

APPENDIX VI

Agency	Final Reports
Chief of Research and Development Department of the Army ATTN: CRDME-1 Washington, D. C. 20310	2
Assistant Chief of Staff for Force Development Department of the Army Washington, D. C. 20310	2
President U. S. Army Maintenance Board Fort Knox, Kentucky 40121	1
Commander Defense Documentation Center for Scientific and Technical Information ATTN: Document Service Center Cameron Station Alexandria, Virginia 22313	2
Commanding General U. S. Army Medical Research and Development Command ATTN: MEDDH-RPA Washington, D. C. 20315	2
Commanding Officer U. S. Army Aeromedical Research Laboratory Fort Rucker, Alabama 36360	2
Project Officer for Life Support Equipment U. S. Army Aviation Systems Command ATTN: AMCPO-LSE P. O. Box 209 St. Louis, Missouri 63166	1
Commanding Officer U. S. Army Board for Aviation Accident Research ATTN: BAAR-LS Fort Rucker, Alabama 36360	1

APPENDIX VI

Agency	Final Reports
Commanding Officer Yuma Proving Ground ATTN: STEYP-TAT Yuma, Arizona 85364	1
President U. S. Army Aviation Test Board ATTN: STEBG-TO Fort Rucker, Alabama 36360	1
Commanding Officer U. S. Army Arctic Test Center ATTN: STEAC-MT APO Seattle 98733	1
Commanding Officer U. S. Army Aberdeen Research and Development Center ATTN: AMXRD-AD Aberdeen Proving Ground, Maryland 21005	1
Deputy Chief of Staff for Logistics ATTN: Directorate of Maintenance Cgief, Maintenance Engineering Division Washington, D. C. 20315	1
Deputy Chief of Staff for Logistics Department of the Army Washington, D. C. 20310	1
Deputy Chief of Staff for Personnel Department of the Army Washington, D. C. 20310	1
Deputy Chief of Staff for Military Operations Department of the Army Washington, D. C. 20310	1
Office of the Chief of Engineers Department of the Army Washington, D. C. 20315	1

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil G. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USAGETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil G. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USAGETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil G. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USAGETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil G. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USAGETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil C. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USACETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil C. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USACETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4.
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil G. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USACETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

AD Accession No.

U.S. Army General Equipment Test, Activity, Fort Lee, Virginia.

ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF WINTER FLIGHT CLOTHING SYSTEM, by Phil G. Delduke, SP4. November 1971, pages, -tables, -illus., 6 Appendices.
(TECOM Project No. 4-EI-485-AAC-008) Unclassified Report

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USACETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeomedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded thattest item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges, and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

Unclassified Report

1. CLOTHING
2. UNDERWEAR
3. WINTER UNDERWEAR
4. FLIGHT CLOTHING, LIGHTWEIGHT
I. DELDUKE, Phil G., SP4
II. Engineering Test of Lightweight Underwear of Winter Flight Clothing System
III. USATECOM 4-EI-485-AAC-008

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Commanding Officer U.S. Army General Equipment Test Activity Fort Lee, Virginia 23801	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3 REPORT TITLE

Engineering Test of Lightweight Underwear of Winter Flight Clothing System

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report

5 AUTHOR(S) (Last name, first name, initial)

Delduke, Phil G., SP4

6 REPORT DATE	7a. TOTAL NO. OF PAGES	7b NO OF REFS
November 1971	45	16

8a. CONTRACT OR GRANT NO b PROJECT NO USATECOM 4-EI-485-AAC-008 c d	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10 AVAILABILITY/LIMITATION NOTICES Distribution limited to U.S. Government Agencies only; test and evaluation; November 1971. Other requests for this document must be referred to Commanding General, U.S. Army Natick Laboratories, Natick, Massachusetts.

11 SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
None	U.S. Army Natick Laboratories Natick, Masschusetts

13. ABSTRACT

An Engineering Test of Winter Flight Clothing System was conducted from January 1971 to October 1971 at USAGETA except for the thermal protection phase which was conducted concurrently at U.S. Army Aeormedical Research Laboratory, Fort Rucker, Alabama, in March 1971. Technical characteristics of the experimental underwear were ascertained and a comparative evaluation made with the standard item.

It was concluded that test item met requirements to a satisfactory degree except for thermal degradation properties, surface resistivity to electrical charges and ability to resist accumulation of electrostatic charges. There was no significant difference between performance of the experimental versus the standard items.

It is recommended that the deficiencies and shortcoming be corrected, and that criteria for electrostatic characteristics be re-evaluated.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Clothing						
2. Underwear						
3. Winter Underwear						
4. Flight Clothing, Lightweight						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
________________________________ ."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
________________________________ ."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
________________________________ ."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (*TS*), (*S*), (*C*), or (*U*).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.