

ASD-TR-72-2

AD 740600

DEVELOPMENT OF A SERIES OF HIGH  
TEMPERATURE RESISTANT FABRICS TO  
REPLACE CURRENT SPECIFICATION NYLON  
AND COTTON FABRICS

Robert Donnelly  
Prodesco, Inc

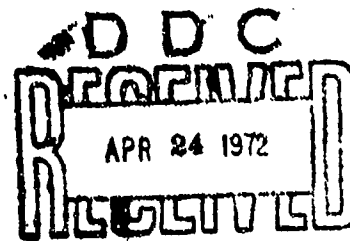
TECHNICAL REPORT ASD-TR-72-2

February 1972

Approved for public release;  
distribution unlimited

Reproduced by  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
Springfield, Va. 22151

LIFE SUPPORT SYSTEM PROGRAM OFFICE  
AERONAUTICAL SYSTEMS DIVISION  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE  
OHIO 45433



78

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

ACQUISITION NO.	
RFSTI	WRITE SECTION <input type="checkbox"/>
NO	COMP SECTION <input type="checkbox"/>
EMP/INDUSTRY	<input type="checkbox"/>
INVESTIGATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
CONT.	AVAIL. CODE OR SPECIAL
A	

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

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) Prodesco Inc 700 Park Avenue, Perkasie, PA 18944		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP N/A	
3. REPORT TITLE DEVELOPMENT OF A SERIES OF HIGH TEMPERATURE RESISTANT FABRICS TO REPLACE CURRENT SPECIFICATION NYLON AND COTTON FABRICS			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report, June 1970 to December 1971			
5. AUTHOR(S) (First name, middle initial, last name) Robert Donnelly			
6. REPORT DATE February 1972		7a. TOTAL NO. OF PAGES 68	7b. NO. OF REFS 5
8a. CONTRACT OR GRANT NO. F33657-70-C-1173		9a. ORIGINATOR'S REPORT NUMBER(S) ASD-TR-72-2	
b. PROJECT NO. Endeavor Number A0188		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) None	
c.			
d.			
10. DISTRIBUTION STATEMENT Approved for public release' distribution is unlimited.			
11. SUPPLEMENTARY NOTES None		12. SPONSORING MILITARY ACTIVITY Life Support System Program Office Aeronautical Systems Division (AFSC) Wright-Patterson AFB, Ohio 45433	
13. ABSTRACT A development program designed to replace flammable fabrics in aircraft is reported. Specification materials used by the Air Force, generally cotton, nylon or combinations of the two, were replaced by aromatic polyamide (Nomex) fabrics of equal or better properties for a given requirement.  Seven different fabrics were developed, tested, and draft specifications suitable for future prototype procurement were written. Serviceability, costs, and large quantity production considerations were not within the scope of this contract.  During this contract, 44 samples were prepared by the contractor, of which 22 were submitted to the Air Force for evaluation. Primarily, staple fabrics were developed because of volume requirements. However, three filament items were developed; two narrow fabrics, and a new warp knit fabric which can serve as a basic fabric for applications requiring moderate stretch characteristics.			

DD FORM 1473  
NOV 65

Unclassified  
Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fabric for Anti-G Suit Seat Cushion Armor Vest Cover Life Preserver Cover Knit Seat Cushion Filament Closure Harness Webbing Flight Clothing Outer Fabric						

Unclassified

See the Classification

ASD-TR-72-2

DEVELOPMENT OF A SERIES OF HIGH  
TEMPERATURE RESISTANT FABRICS TO  
REPLACE CURRENT SPECIFICATION NYLON  
AND COTTON FABRICS

Robert Donnelly  
Prodesco, Inc

Approved for public release;  
distribution unlimited

## FOREWORD

This final technical report was prepared by Prodesco, Inc., 700 Park Avenue, Perkasio, Pa. 18944, under Contract AF33657-70-C-1173, Development of Nomex Fabrics. The effort is part of Program 412A Endeavor A0188, entitled Nomex Fabric Development. The program was sponsored by the Life Support System Program Office. The program was under the direction of Mrs. Lee Rock, ASD/SML-4, of the sponsoring organization with technical direction provided by the Nonmetallic Materials Division, Air Force Materials Laboratory, with Mr. P.C. Opt as Program Engineer.

This report covers development over a time period from June 1970 to December 1971. This report was submitted for approval December 1971.

The author gratefully acknowledges the assistance of the following companies who performed supportive effort in this development: E.I. du Pont de Nemours & Co., Inc., Textile Fibers Department and Fabrics & Finishes Department; China Grove Cotton Mills Company; Bally Ribbon Mills, Inc.; U.S. Army Natick Laboratories.

This technical report has been reviewed and is approved.



ALBERT P. LOVELADY, Col, USAF  
System Program Director  
Life Support System Program Office  
Deputy for Subsystems

## ABSTRACT

A development program designed to replace flammable fabrics in aircraft is reported. Specification materials used by the Air Force, generally cotton, nylon or combinations of the two, were replaced by aromatic polyamide (Nomex) fabrics of equal or better properties for a given requirement.

Seven different fabrics were developed, tested, and draft specifications suitable for future prototype procurement were written. Serviceability, costs, and large quantity production considerations were not within the scope of this contract.

During this contract, 44 samples were prepared by the contractor, of which 22 were submitted to the Air Force for evaluation. Primarily, staple fabrics were developed because of volume requirements. However, three filament items were developed; two narrow fabrics, and a new warp knit fabric which can serve as a basic fabric for applications requiring moderate stretch characteristics.

## TABLE OF CONTENTS

	PAGE
I Introduction	1
II Fabric for Anti-G-Suit	3
III Seat Cushion/Armor Vest Cover	15
IV Life Preserver Cover	22
V Knit Seat Cushion	30
VI Filament Closure	36
VII Harness Webbing	41
VIII Flight Clothing Outer Fabric	47
IX Conclusions	63
X Recommendations	64
Appendix I Contract Administration Project Control	65
Appendix II Standard Autoclave Heat Set Procedure Used on Nomex Fabrics	66
Appendix III Materials (Yarn)	67
References	68

## LIST OF ILLUSTRATIONS

FIGURE		PAGE
1	Anti-G-Suit Fabric, Project 5272-053	6
2	Anti-G-Suit Fabric, Project 5272-056, sample #1	8
3	Anti-G-Suit Fabric, Project 5272-056, sample #2	9
4	Anit-G-Suit Fabric, Project 5272-070	12
5	Seat Cushion/Armor Vest, Project 5272-055	18
6	Seat Cushion/Armor Vest, Project 5272-071	20
7	Cast Coating Process (Two Step)	22
8	Life Preserver Cover - Substrate Fabric, 5272-055	23
9	Calendering Coating Process	26
10	Life Preserver Cover Substrate Fabric, 5272-071	28
11	Fastener Tape, Project 5272-065	38
12	Fastener Tape (Research Sample) Project 5272-066	39
13	Harness Webbing, 2 Inch, Project 5272-062	43
14	Harness Webbing, 1 1/2 Inch, Project 5272-067	44
15	Flight Clothing Outer Fabric, Project 5272-064	49
16	Flight Clothing Outer Fabric, Project 5272-063	54
17	Flight Clothing Outer Fabric, Project 5272-060	58
18	Flight Clothing Outer Fabric, Project 5272-073	60

## LIST OF TABLES

TABLE		PAGE
I	Anti-G-Suit Fabric Properties	4
II	Anti-G-Suit Fabric Compared to MIL-C-4487	5
III	Anti-G-Suit Fabric Properties	11
IV	Anti-G-Suit Fabric	14
V	Seat Cushion/Armor Vest Fabric	16
VI	Seat Cushion/Armor Vest Fabric	17
VII	Seat Cushion/Armor Vest Fabric	21
VIII	Life Preserver Cover	24
IX	Life Preserver Cover	27
X	Life Preserver Cover	29
XI	Knit Seat Cushion Test Results	31
XII	Knit Seat Cushion Fabrics	32
XIII	Knit Seat Cushion Fabrics	35
XIV	Filament Closure Tape	37
XV	Filament Closure Tape	40
XVI	Harness Webbing - 2 Inch	42
XVII	Harness Webbing - 1 1/2 Inch	46
XVIII	Flight Clothing Outer Fabric	48
XIX	Flight Clothing Outer Fabric	51
XX	Flight Clothing Outer Fabric	54
XXI	Flight Clothing Outer Fabric	56
XXII	Flight Clothing Outer Fabric	59
XXIII	Flight Clothing Outer Fabric	62

## SECTION I

### INTRODUCTION

The goal of this program was the development of a series of Nomex\* fabrics of optimum construction to replace current specification nylon and cotton fabrics used in numerous aerospace applications.

The unique property that established Nomex as the basic material for this program was its resistance to fire and heat. Nomex is the only commercially available fiber with desirable flame and heat resistance properties coupled with acceptable textile processing qualities, and good fabric properties.

Because of the volume of certain fabrics consumed by the Air Force and the limited production facilities for continuous filament Nomex, at the time this program was initiated, the majority of materials developed used staple spun yarns. The exceptions were: knitted seat cushion fabric, narrow tape, and a 1 1/2 inch webbing.

According to the statement of work for the contract, the development of materials was to be accomplished in two distinct phases. Number one was referred to as prototype fabrics, knitted or woven, in short lengths (7-10 yards) for each of the areas of development. These fabrics were to be evaluated by the contractor and by the Air Force Materials Laboratory using test methods listed in the appropriate specifications. The second phase was to produce yardage of a selected fabric for each development. These were termed "research samples" by the Air Force and were to be used for production evaluation, and physical property testing in addition to prototype fabrication of various end items. All materials developed under this contract proceeded through the two phases of effort.

The seven different materials developed under this contract were initiated at approximately the same time. The prototype phase of several projects was completed before that of the others, this meant that during the progression of the contract certain materials were in the "research sample" phase while others were still in the prototype development. Monthly chronological reporting of all project events would show a large amount of over-lapping of programs. In order to clarify the reporting of the development of

---

\* Registered trade mark for E.I. du Pont de Nemours high temperature resistant aromatic polyamide.

these projects, it has been decided to report each distinct material development separately from concept through prototype to research sample production. They will be reported in the following order:

USAGE	SPECIFICATION REPLACEMENT	REPORT SECTION NO.
Anti-G-Suit Fabric	MIL-C-4487	II
Seat Cushion, Armor Vest, and Other Applications	MIL-C-7219, Type 3 MIL-C-557, Type 1 MIL-C-7219, Type 3 MIL-C-557, Type 2	III
Life Preserver Cover	MIL-C-8135-A	IV
Knit Seat Cushion Cover	Stretch Knit Nylon Fabric, SOW para. A.2	V
Filament Closure Tape	MIL-C-8363, Type 1	VI
Harness Webbing, 1 1/2"	MIL-C-17337, 1.5"	VII
Flight Clothing Outer Fabric	MIL-C-4294, Type 2 Class C	VIII

## SECTION II

### FABRIC FOR ANTI-G-SUIT

#### 1. PROTOTYPE DEVELOPMENT FABRIC, 5272-053

The objectives were a medium weight, high air permeability fabric with balanced tensile and elongation. A warp was prepared, 24 inches wide using 50/2 Nomex at a construction of 90 ends per inch for a total of 2160 ends. The warp was drawn in on 12 harness and placed into a narrow silk loom for weaving.

Sample #1 was to be a plain weave, using the same filling yarn as warp at 90 picks per inch. The construction of this fabric was such that 90 picks could not be woven. Sample #2 was designed using a 2 x 2 basket weave and a one-yard head end was woven at 90 picks. This sample appeared rather tight so a third weave was prepared in a 3 x 3 basket weave configuration. This weave is not normally used in the textile trade, but is not difficult to make and could easily be done commercially. This weave would yield more permeability and a greater tear resistance to the fabric.

The samples were finished as below and tested for physical properties.

1. Jig scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
at 180° F. for one-half hour.
2. Dry.
3. Autoclave using Nomex heat set procedure.
4. Semi Decate to smooth fabric;  
2 minutes steam, 2 minutes air

TABLE I  
 ANTI-G-SUIT FABRIC PROPERTIES  
 (Project 5272-053 Head Ends)

<u>TEST</u>	<u>5272-053 Sample-2</u>	<u>5272-053 Sample-3</u>
Yarns/inch warp x filling	96 x 96	96 x 96
Weight ounces/yd <sup>2</sup>	5.31	5.21
Breaking Strength lbs./inch Ravel Strip Method warp x filling	138 x 136	134 x 139
% Elongation @ Break warp x filling	39 x 35	35 x 34
Tearing Strength (lbs.) Tongue Method warp x filling	11 x 12	32 x 32
Air Permeability @ 0.5" water pressure (ft <sup>3</sup> /ft <sup>2</sup> /min.)	63.7	79.1

Based on the test results (tear strength and air permeability) of the sample head ends, Sample 3 was selected as the fabric to be woven in a minimum seven-yard length for evaluation by the Air Force.

An additional weave was prepared to improve the air permeability of the fabric. This was a 3 x 4 mock leno weave in which the warp and filling ends group together more closely than in regular weaves. Several yards of this fabric were also made.

The samples were finished according to the following procedure:

1. Jig scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
at 180° F. for one-half hour.
2. Dry.
3. Autoclave using Nomex heat set procedure.

4. Semi Decate to smooth fabric;

2 minutes steam, 2 minutes air

The test results from Sample #4 did not show an improvement and the sample was rejected on this basis. The air permeability was less as was the tearing strength than Sample #3, and since the objective of this trial was to improve air permeability and keep tearing strength the same, it was not considered a success.

Table II lists the properties of the prototype submitted to the Air Force compared with the sample of MIL-C-4487 tested at Prodesco and the specification requirements.

TABLE II  
ANTI-G-SUIT FABRIC COMPARED TO MIL-C-4487  
(Project 5272-053 Sample #3)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-053 Sample #3</u>	<u>MIL-C-4487(1)</u>	<u>SPECIFICATION</u>
Weight (oz/yd <sup>2</sup> )	5041	5.35	4.42	4.50 (max.)
Thread Count	5050	96 x 99	188 x 82	184 x 82 (min.)
Breaking Strength (lbs.)	5104	129 x 124	130 x 115	110 x 110 (min.)
Elongation @ Break (%)	5104	35 x 37	13 x 33	- x -
Tearing Strength (lbs.)	5134	26 x 32	7 x 11	8 x -
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	72	48.5	110 (max.) 40 (min.)
Abrasion (2) cycles to destruct	5302.1	954	1495	----

(1) Sample tested at Prodesco

(2) One specimen only

Figure 1 is a copy of the fabric construction sheet used to produce these samples. The drawing-in draft used was a "skip" draw. It should not be necessary to use this in production.

Figure 1

Anti-G-Suit Fabric - Project 5272-053

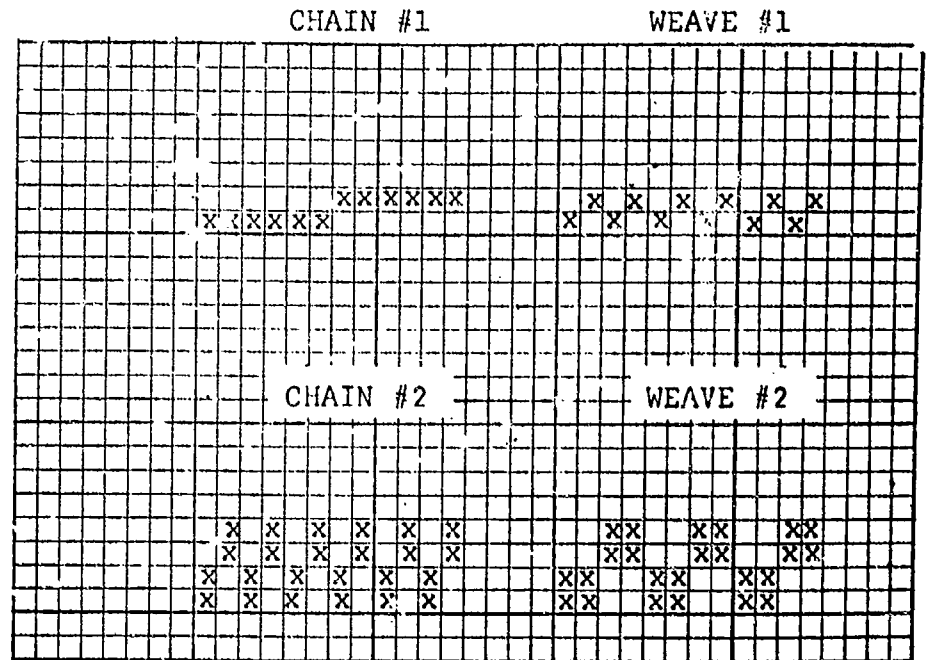
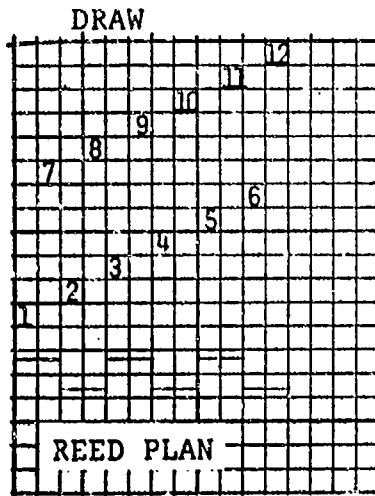
LOOM SETTING

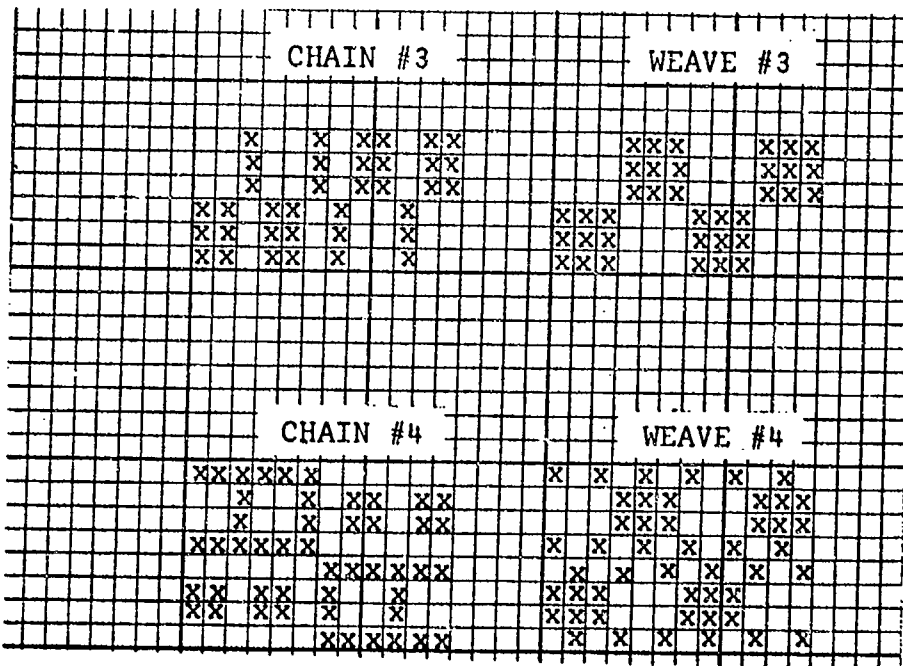
	BEAM 1	BEAM 2	BEAM 3	Selvage
Ends in Warp	2160			Yarn as warp
Reed No.	45			12 doubles Each Side
Ends Per Dent	2			Tape weave
Reed Width	24"			
Beams Used	1			
Pick Wheel	90			

OFF-LOOM DATA

Ends Per Inch	_____
Picks Per Inch	_____
Cloth Width	_____
Take-up	_____
Weight Per Sq. Yd.	_____

Warp and Filling Yarns - 50/2 Nomex Sage Green, Merge 114168 Type-452





SAM.	DR #	HC #	RC #	PX	PX WH	WEAVE INSTS.	WOVEN DATE	BY	O.K.	BOX 1	
1	1	1	SOLID ↓	90		HE" YDS. YDS.				50/2 Nomex Merge 114168	← Won't Run
2	1	2		90		HE" 36 YDS. YDS.					
3	1	3		90		HE" 36 YDS. 8.5 YDS.					
4	1	5		90		HE" W.O. - 2 yds. YDS. YDS.					↓

2. PROTOTYPE DEVELOPMENT FABRIC 5272-056

The Air Force requested the Contractor to make a comparative cost estimate for fabrics made with 50/2 Nomex yarn and 24/1 Nomex yarn. The following is a comparison of those costs:

COST OF 2-PLY VS. SINGLES

5.5 oz/yd<sup>2</sup> @ 50" = .475 lb/yd.

Assume \$12.48/lb. for 24/1 Nomex yarn

Add 0.62/lb. for 50/2

Materials Cost/yd. - 24/1 - \$5.95

- 50/2 - \$6.25

All other costs being equal\* 50/2 is \$0.30/yd more costly. (\* sizing costs \$.01 - \$.02/yard extra.)

This is 5% more material which would contribute approximately 3% - 4% to the total cost per yard.

A new version of the Anti-G-Suit fabric was started. It was designed to substitute for fabric 5272-053, sample #3, except that the weave would be a 2 x 2 basket instead of a 3 x 3 basket. The yarns used were 24/1 as opposed to 50/2. An in-loom construction of 90 ends x 90 picks was prepared.

Following are fabric construction sheets for two samples made on this warp.

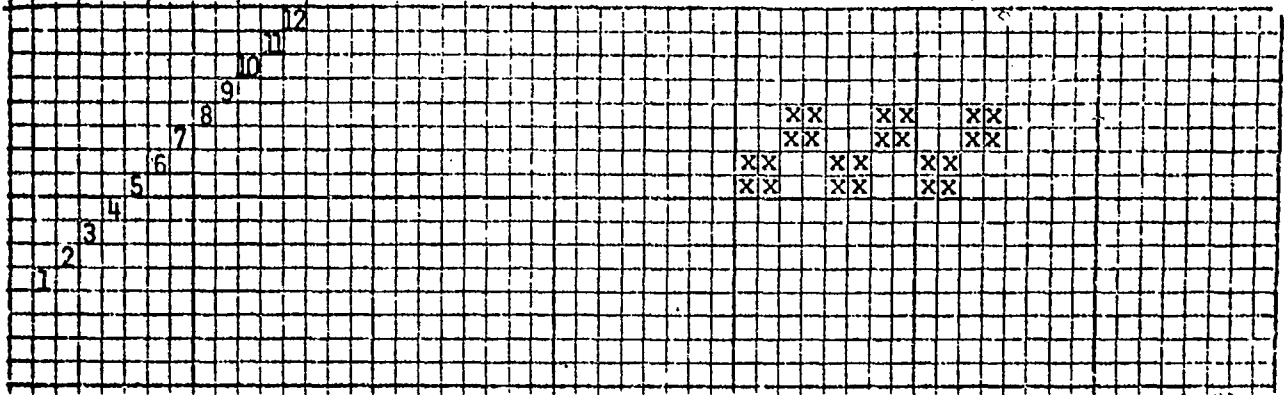
Figure 2

Anti-G-Suit Fabric - Project 5272-056 (Sample #1)

LOOM SETTING				OFF-LOOM DATA	
Ends in Warp	BEAM 1	BEAM 2	BEAM 3	Selvage	Ends Per Inch _____
Reed No.	2160			Yarn AS. WARP	Picks Per Inch _____
Ends Per Dent	45			12 doubles Each Side	Cloth Width _____
Reed Width	2			Tape weave	Take-up _____
Beams Used	24" + Selv.				Weight Per _____
Pick Wheel	1				Sq. Yd. _____

DRAWING DRAFT #1

CHAIN #1



SAM.	DR #	HC #	BC #	PX	PX MI	WEAVE INSTS.	WOVEN DATE	BY	O.K.	BOX 1
1	1	1	So id	90		HE" 36 YDS. 8 YDS.				24/1 Nomex Sage Green 4.75 T.M.

A second fabric with a reduced construction to compensate for the difference in yarn characteristics, designated sample 2, utilized an in-loom construction of 86 x 86.

Figure 3

Anti-G-Suit Fabric - Project 5272-056 (Sample #2)

LOOM SETTING

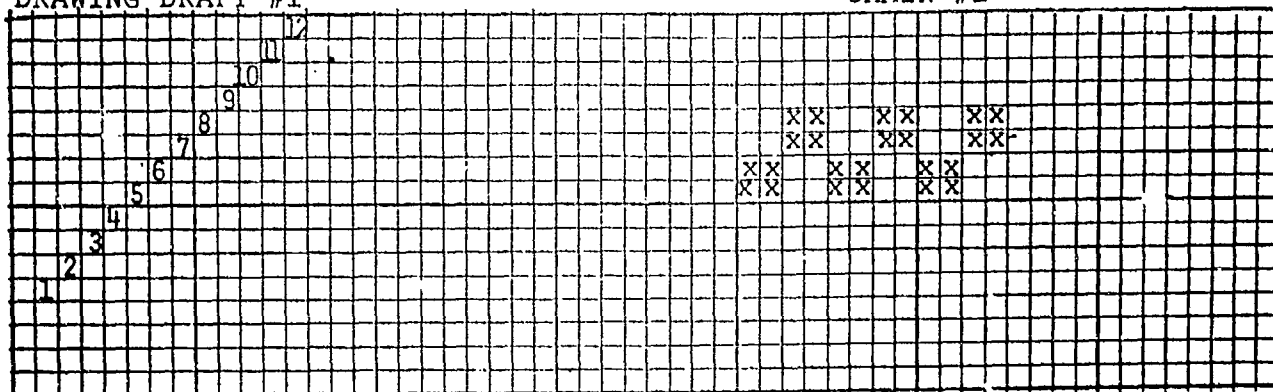
	BEAM 1	BEAM 2	BEAM 3	
Ends in Warp	2160			Selvage
Reed No.	43			Yarn as warp
Ends Per Dent	2			12 doubles Each Side
Dent Width	25" + Selv.			Tape weave
Beams Used	1			
Pick Wheel				

OFF-LOOM DATA

Ends Per Inch	_____
Picks Per Inch	_____
Cloth Width	_____
Take-up	_____
Weight Per Sq. Yd.	_____

DRAWING DRAFT #1

CHAIN #1



SAM.	DR #	HC #	BC #	PX	PX WII	WEAVE INSTS.	WOVEN DATE	BY	O.K.	BOX 1	
2	1	1	S <sub>01</sub> i <sub>1</sub>	86		HE <sup>11</sup> 36 YDS. 8 YDS.				24/1 Nomex Sage Green 4.75 T.M.	

Both Samples were finished according to the following procedure:

1. Jig scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
  
at 180° F. for one-half hour.
2. Dry.
3. Autoclave using Nomex heat set procedure.
4. Semi Decate to smooth fabric;  
  
2 minutes steam, 2 minutes air

The finished fabrics were tested for physical properties and forwarded to the Government. Those physical properties are listed in Table III.

TABLE III  
ANTI-G-SUIT FABRIC PROPERTIES  
(Project 5272-056)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-056 Sample #1</u>	<u>5272-056 Sample #2</u>
Weight (oz/yd <sup>2</sup> )	5041	5.77	5.79
Thread Count (W x F)	5050	99 x 95	92 x 89
Breaking Strength (lbs/in : W x F)	5104	140 x 126	128 x 115
Elongation @ Break (% : W x F)	5104	38.4 x 41.8	39.0 x 34.2
Tearing Strength (lb. : W x F)	5134	15 x 16	19 x 17
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	68	90

3. RESEARCH SAMPLE, PROJECT 5272-070

Fabric 5272-056, sample 2, was selected by the Air Force to be produced in Research Sample size. A warp was prepared for weaving with 4300 ends of 24/1 Nomex yarn, 50 inches wide, 200 yards long. It was sized with a PVA/wax sizing to aid in weaving.

The warp was set in a C-loom at a construction of 86 ends and 86 picks. A sample was woven and finished for construction. It had a finished construction of 90 x 92 and a weight of 5.6 ounces per square yard. This was within a reasonable tolerance of the prototype sample, so the remaining 200 yards of warp was woven out.



The fabric was finished according to the following procedure:

1. Scour open width on continuous scouring range at 160° F. in scouring solution of 1.0 g/l of TSP and detergent.
2. Dry at 300° F. to set construction.
3. Autoclave heat set using standard procedure for Nomex.
4. Pad on antistat solution: 6.6% Aston 123  
2.7% Accelerator EN  
pH - 6.5

Wet pick up 50-60%.

5. Dry at 300° F., cure at 350° F. for 1.5 minutes.

The finished fabric was inspected and samples were taken at four places for testing. Table IV below compares the physical properties on the research sample run versus those of the prototype sample (5272-056, sample 2).

All test results are within a reasonable tolerance with the exception of the tongue tear results. Possible reasons for this increase could be different finishing techniques used in production, the addition of the antistat which would act as lubricant, or a different twist in the yarn which could make a softer, more elastic fabric.

TABLE IV  
 ANTI-G-SUIT FABRIC  
 (Research Sample, Project 5272-070)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-070</u>	<u>5272-056 Sample #2</u>
Weight (oz/yd <sup>2</sup> )	5041	5.43	5.79
Thread Count (W x F)	5050	91 x 87.5	92 x 89
Breaking Strength (lbs/in : W x F)	5104	122.8 x 117	128 x 115
Elongation at Break (% : W x F)	5104	43.2 x 39.35	39.0 x 34.2
Tearing Strength (lb. : W x F)	5134	36.4 x 35.5	19 x 17
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	110.48	90

## SECTION III

### SEAT CUSHION - ARMOR VEST COVER

#### 1. PROTOTYPE FABRIC 5272-055

The fabric to be used for seat cushion, armor vest cover and life preserver cover was designated as Project 5272-055. The objective of this project was to prepare a rugged, duck-type fabric utilizing spun Nomex. The fabric was to have good physical properties, abrasion resistance, etc.

A warp was prepared 24 inches wide using 20/2 Nomex yarn in a construction of 58 ends per inch for a total of 1406 ends in the warp. The warp was drawn into 8 harness and placed in a heavy duty loom for weaving a maximum construction fabric. A sample was woven at 44 picks and finished as follows:

1. Jig scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
at 180° F. for one-half hour.
2. Dry.
3. Autoclave using Nomex heat set procedure.
4. Semi Decate to smooth fabric;  
2 minutes steam, 2 minutes air

The fabric was tested along with a similar sample of higher pickage. They were designated as Sample 1 and 1A, with the higher pickage being Sample 1A. The physical test results on those fabrics are as follows:

TABLE V  
SEAT CUSHION/ARMOR VEST FABRIC  
(Head End Properties)

<u>TEST</u>	<u>5272-055 Sample-1</u>	<u>5272-055 Sample-1A</u>
Yarns/inch warp x filling	60 x 45	61 x 48
Weight ounces/yd <sup>2</sup>	7.79	7.88
Breaking Strength (lbs/in) Ravel Strip Method warp x filling	228 x 171	216 x 162
% Elongation @ Break warp x filling	65.8 x 34.2	63.3 x 27.6
Tearing Strength (lbs.) Tongue Method warp x filling	18 x 16	18 x 14
Air Permeability @ 0.5" water pressure av. (ft <sup>3</sup> /ft <sup>2</sup> /min.)	11.7	7.4

After these tests were conducted, the warp was placed in a larger loom and additional weaving was done. The objective of this additional weaving was to construct more picks (51-52) per inch for greater strength and lower air permeability.

After discussing the test results of this fabric (sample #3) with the Air Force, a decision was made to reduce the fabric construction. This changed construction reflected the opinions of the Air Force and the contractor that sample #3 was "over-engineered" for the intended uses. A fabric weighing approximately 7.5 ounces with balanced tensile strengths would be better for these applications. The warp was re-reeded to 46 ends per inch and sample #4 was woven at 48 picks per inch. The test results of the finished sample are shown in Table VI.

Twenty yards of this fabric were woven at 47 picks and finished, tested and submitted as a prototype.

TABLE VI  
SEAT CUSHION/ARMOR VEST FABRIC  
(Prototype Fabric - Project 5272-055)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>Sample #3</u>	<u>HEADEND Sample #4</u>	<u>PROTOTYPE Sample #4</u>
Yarns/inch (W x F)	5050.1	60 x 53	50 x 52	50.5 x 51
Weight (oz/yd <sup>2</sup> )	5041	9.0	7.7	7.5
Thickness (inch)	5030	0.027	0.021	0.021
Strength Breaking (lbs/inch) W x F	5104	210 x 200	190 x 189	194 x 195
% Elongation @ Break W x F	5104	65.0 x 30	56 x 47	55 x 47
Tearing Strength (lbs) W x F	5134	16 x 16	19 x 17	18 x 17
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	2.2	-----	20

Both head end and prototype were finished according to the following procedure:

1. Jig scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
at 180° F. for one-half hour.
2. Dry.
3. Autoclave using Nomex heat set procedure.
4. Semi Decate to smooth fabric;  
2 minutes steam, 2 minutes air

Figure 5 is a copy of the fabric construction sheet used to produce these samples.



SAM.	DR #	HC #	BC #	PX	PX WTI	WEAVE INSTS.	WOVEN DATE	BY	O.K.	BOX 1	BOX 2
1	1	1	Spl.	41		HE" 36 YDS. YDS.				20/2 Nomex Sage Green	
1A	1	1A	1A	44		HE" 36 YDS. YDS.				20/2 Nomex Sage Green	Empty Shuttle
2	X	X	X	X	X	HE" X YDS. YDS.				X X	
3	1	1	Spl.	51/ 52		HE" 12 YDS. 10 YDS.				20/2 Nomex Sage Green	
						HE" YDS. YDS.					
RE-REED TO 23 REED @ 2/DENT @ 30.5"											
						HE" 36 YDS. 20 YDS.				20/2 Nomex Sage Green	
4	1	1	Spl.	48/ 47							

2. RESEARCH SAMPLE, PROJECT 5272-071

Fabric number 5272-055, sample 4 was selected for production. Two warps were prepared, each 325 yards long at a construction of 2300 ends, 50 inches wide.

These warps were set up in S-looms at a construction of 46 ends x 47.5 picks. A head end was woven from each loom and checked for construction.

The construction was 50 x 50 with a weight of 7.6 ounces per square yard which was within a reasonable tolerance of the sample approved by the Air Force (5272-055, sample 4).

The 750-yard long warps containing 2300 ends were woven out as in the fabric construction detailed below.



610 yards of greige cloth were produced from these warps for finishing. The procedure used in finishing the fabric is as follows:

1. Scour open width on continuous scouring range at 160° F. in scouring solution of 1.0 g/l of TSP and detergent.
2. Dry at 300° F. to set construction.
3. Autoclave heat set using standard procedure for Nomex.
4. Pad on antistat solution: 6.6% Aston 123  
2.7% Accelerator EN  
pH - 6.5

Wet pick up 50-60%.

5. Dry at 300° F., cure at 350° F. for 1.5 minutes.

The fabric was inspected and eight samples removed for testing for physical properties. Table VII shows those properties in comparison with the prototype sample.

TABLE VII

SEAT CUSHION/ARMOR VEST FABRIC

(Research Sample - Project 5272-071)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-071 RESEARCH SAMPLE</u>	<u>5272-055 Sample #4</u>
Weight (oz/yd <sup>2</sup> )	5041	7.22	7.5
Thread Count (W x F)	5050	49 x 49	50.5 x 51
Breaking Strength (lbs: W x F)	5104	170 x 170	194 x 195
Elongation @ Break (%: W x F)	5104	57.3 x 47.1	55 x 47
Tearing Strength (lbs: W x F)	5134	29 x 32	18 x 17
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	32.26	20

## SECTION IV

### LIFE PRESERVER COVER

#### 1. PROTOTYPE PROJECT 5272-068

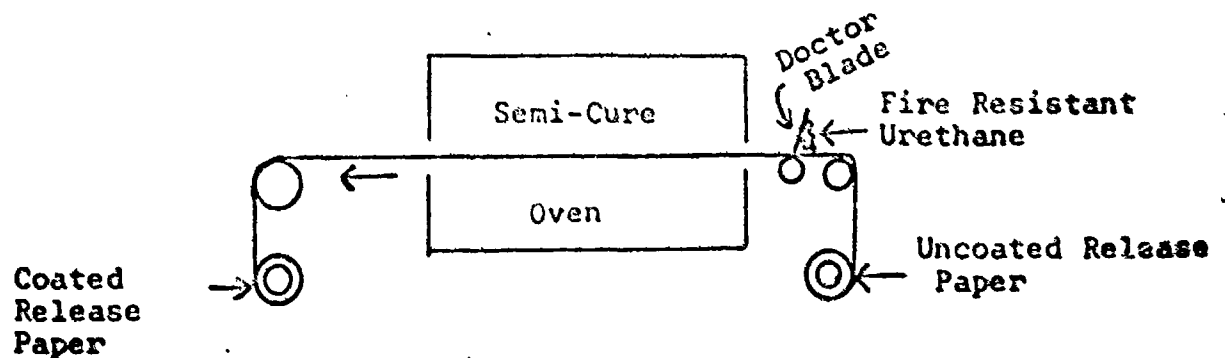
Fabric number 5272-055, sample 4, described in the previous section (III), was submitted to Incopa Industries, Inc. of Boston, Massachusetts, for application of a coating. The objectives of the coating experiments were as follows:

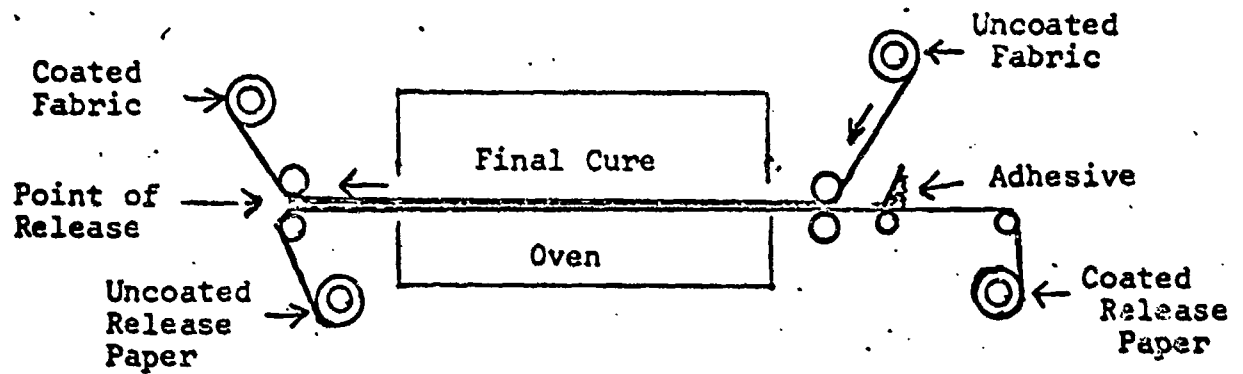
1. A coating that would not add flammability to the Nomex substrate.
2. A coating that would smooth the Nomex fabric for low friction during life vest inflation.
3. A coating that would add as little weight as possible to the Nomex substrate fabric.

Incopa Industries informed the contractor that the coating system used would be a "cast" coating of fire resistant polyurethane material. Cast coating is a two-step process where the coating material is spread onto a treated paper, semi-cured, then applied to the fabric with adhesive and cured. Figure 7 shows these operations.

Figure 7

#### Cast Coating Process (Two Step)





The coated fabric received from Incopa Industries was inspected and tested for physical properties. Inspection revealed numerous coating defects such as bubbles, voids, heavy spots and wrinkles. When investigating this problem with Incopa, they stated that their process for coating this material was such that no adjustments could be made on settings and procedures before the ten-yard sample was through the coating process.

The fabric construction work sheet showing production details follows.

Figure 8

Life Preserver Cover - Substrate Fabric 5272-055

LOOM SETTING

	BEAM 1	BEAM 2	BEAM 3	Selvage
Ends in Warp	1406			Yarn _____
Reed No.	23			_____ Each Side
Ends Per Dent	2			
Reed Width	30.5			
Beams Used	1			
Pick Wheel	47			

OFF-LOOM DATA

Ends Per Inch	50.5
Picks Per Inch	51
Cloth Width	28
Take-up	6%
Weight Per Sq. Yd.	7.5 ozs.

Warp and Filling Yarns: 20/2 Nomex Sage Green, Type 452, Merge 114168



<u>TEST</u>	<u>CCC-T-191b</u> <u>METHOD</u>	<u>5272-055</u>	<u>MIL-C-8135A</u>
(PROPERTIES BELOW FOR COATED CLOTH)			
Thickness (inches)	5030	0.020 ± 0.002	0.0155 ± 0.0015
Weight (oz/yd <sup>2</sup> )	5041	10.50	12.70
Breaking Strength (W x F) (Lbs.)	5100	310 x 300	450 x 350
Tearing Strength (W x F) (Lbs.)	5134	12 x 12	20 x 20
Elongation % (W x F)	5100	50 x 52	35 x 30
Coating Adhesion	4.3.2.3	23.5	12.
Acidity pH	2811	(1)	5 - 9

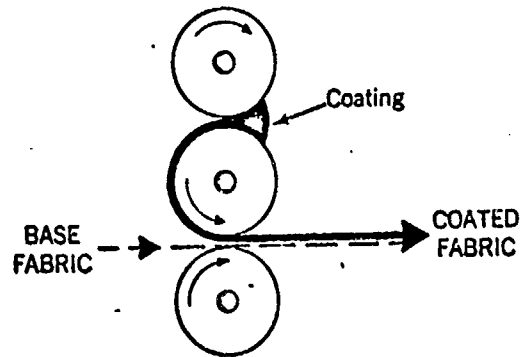
---

(1) Not tested on this sample.

## 2. PROTOTYPE PROJECT 5272-069

Approximately 30 yards of uncoated fabric was forwarded to E. I. du Pont de Nemours, Fairfield, Connecticut plant. This was fabric number 5272-055, sample 4, which has been reported previously. The fabric was to be calender coated with Hypalon according to their procedure SRO-835. There was not enough time to allow for an experimentation in changing coating weight, so the contractor accepted a standard procedure from DuPont. The future run on this fabric was to be modified with a lighter weight coating if desired. Figure 9 is a sketch of the calendering of coatings extracted from DuPont Bulletin X-197.

Figure 9  
Calendering Coating Process



Calendering is the most economical and practical method for applying a coating of Hypalon or neoprene on a continuous-production basis. Productivity is excellent and processing costs are low, particularly for thick coatings. Equipment can be designed for coating the base fabric on one side (3-roll calender) or on both sides (4-roll calender).

The coated fabric was tested and forwarded to the Government for further testing. The test results are listed in Table IX. Although there was approximately four ounces more coating on this fabric than 5272-068, it is softer and more flexible.

TABLE IX  
LIFE PRESERVER COVER  
(Prototype - Project 5272-069)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>(COATED CLOTH PROPERTIES) 5272-069</u>	<u>MIL-C-8135A</u>
Thickness (inches)	5030	0.021	0.0155 + 0.0015
Weight (oz/yd <sup>2</sup> )	5041	14.6	12.70
Breaking Strength (W x F) (Lbs.)	5100	362 x 327	450 x 350
Tearing Strength (W x F) (Lbs.)	5134	13 x 12	20 x 20
Elongation % (W x F)	5100	43.6 x 52.2	35 x 30
Coating Adhesion	4.3.2.3	Not Strippable	12.
Acidity pH	2811	(1)	5 - 9

(1) Not tested on this sample.

The contractor received a letter from E. I. du Pont de Nemours, Fabrics and Finishes Department, stating the conditions under which the 100-yard piece should be run. The weight of the coating could only be reduced to eight ounces minimum. A lighter weight coating could be applied but would increase the cost and be less efficient. Our recommendation was that the eight ounce in this particular application will not be a deficiency and should be used.

### 3. RESEARCH SAMPLE, PROJECT 5272-072

Two rolls containing a total of 197 yards were extracted from lot 5272-071 and re-labeled 5272-072. These rolls were forwarded to the Fairfield plant of the DuPont Corporation along with Prodesco purchase order number 10336 to cover the cost and construction details for coating with eight ounces of DuPont Compound 271-28-1. Details were not available from DuPont regarding the specific equipment and conditions for coating.

The coated fabric was tested for physical properties. Table X compares the uncoated and coated fabric properties for 5272-072 with the properties for 5272-069, the Prototype Sample. Figure 10 is a fabric construction sheet for the substrate fabric, 5272-071.

Figure 10

Life Preserver Cover Substrate Fabric 5272-071

LOOM SETTING

	BEAM 1	BEAM 2	BEAM 3	Selvage
Ends in Warp	2300			Yarn as warp
Reed No.	23		12	doubles Each Side
Ends Per Dent	2			
Reed Width	50"			
Beams Used	1			
Pick Wheel				

OFF-LOOM DATA

Ends Per Inch	_____
Picks Per Inch	_____
Cloth Width	_____
Take-up	_____
Weight Per Sq. Yd.	_____

Warp & Filling Yarns: 20/2 Nomex Sage Green, Type 452

DRAW				HARNES CHAIN				WEAVE			
			8								
		7									
	6										
5			4								
		3									
	2										
1											

SAM.	DR #	HC #	RC #	PX	PX MI	WEAVE INSTS.	NOVEN DATE	BY	O.K.	BOX 1
1	1	1	SOLID	47.5		HE" YDS. W.O. 610 yds. YDS.				20/2 Nomex Sage Green Type 452

TABLE X

## LIFE PRESERVER COVER

(Research Sample - Project 5272-072)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-055 Sample #4</u>	<u>5272-071 RESEARCH SAMPLE</u>
Weight (oz/yd <sup>2</sup> )	5041	7.5	7.22
Thread Count (W x F)	5050	50.5 x 51	49 x 49
Breaking Strength (lbs: W x F)	5104	194 x 195	170 x 170
Elongation @ Break (%: W x F)	5104	55 x 47	57.3 x 47.1
Tearing Strength (lbs: W x F)	5134	18 x 17	29 x 32
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	20	32.26

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-069 PROTOTYPE</u>	<u>5272-072 RESEARCH SAMPLE</u>
Thickness (inches)	5030	0.021	0.0203
Weight (oz/yd <sup>2</sup> )	5041	14.6	14.3
Breaking Strength (lbs: W x F)	5100	362 x 327	302.4 x 296.8
Tearing Strength (lbs: W x F)	5134	13 x 12	11.5 x 11.1
Elongation @ Break (%: W x F)	5100	43.6 x 52.2	45.1 x 45.1
Coating Adhesion	4.3.2.3	Not Strippable	Not Strippable

## SECTION V

### KNIT SEAT CUSHION

#### 1. PROTOTYPE FABRIC DEVELOPMENT

The primary objective of the knit seat cushion cover project was to develop a knitted fabric for use as a top cover for various seat cushion applications in the aircraft. Warp knit fabrics could be considered for other applications where dynamic stretch or ease of fabrication through stretch would be an advantage. A three-part fabrication program was initiated to explore the possibilities of warp knit fabrics.

Project 5272-057 - 100% Filament Tricot 20 gauge  
Project 5272-058 - 100% Staple Raschel 48 gauge  
Project 5272-059 - Combination Raschel 48 gauge

Each project had three basic fabrics planned:

Sample #1 - Regular Jersey stitch  
Sample #2 - Reverse Jersey stitch  
Sample #3 - An Atlas stitch

A weight range of 7 to 9 ounces per square yard was targeted for these fabrics. Head ends were knit from each fabric and finished as follows:

1. Jig scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
at 180° F. for one-half hour.
2. Dry.
3. Autoclave using Nomex heat set procedure.
4. Semi Decate to smooth fabric;  
2 minutes steam, 2 minutes air

Evaluation of the head ends included visual and physical testing. The table below gives the results of these tests.

TABLE XI

KNIT SEAT CUSHION TEST RESULTS

(Head Ends, Prototype Projects 057, 058, 059)

TEST	5272-057			5272-058			5272-059		
	Sample #1	Sample #2	Sample #3	Sample #1	Sample #2	Sample #3	Sample #1	Sample #2	Sample #3
Yarns/inch wales x courses	29 x 32	26 x 32	28 x 31	27 x 36	30 x 40	30 x 40	25 x 40	25 x 39	25 x 39
Height ounces/yard <sup>2</sup>	8.59	8.15	8.41	7.10	6.26	6.26	7.19	7.54	7.54
Burst Strength Ball Test (lbs.)(1)	150+	150+	150+	150+	150+	150+	150+	150+	150+
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.) average	144	150	290	217	254	254	N. T.	N. T.	N. T.
Abrasion (2) cycles to destruct	2847	2100	2553	900	787	787	912	1427	1427
Stretch % (3) wales x courses	28.3 x 73	30 x 60	26 x 73	46 x 70	70 x 46	70 x 46	39 x 40	40 x 50	40 x 50
Set % wales x courses	3.3 x 3.3	3.3 x 3.3	3.3 x 3.3	3.3 x 3.3	3.3 x 3.3	3.3 x 3.3	3.3 x 8.4	3.3 x 6.7	3.3 x 6.7

NOT TESTED, TOO LIGHT

NOT TESTED, BAD APPEARANCE

(1) Maximum load on testing machine - 150 pounds; samples did not burst at this load.

(2) "0" emery paper, 3 psi diaphragm, 2 pound load.

(3) Specimen is 9" x 3" long dimension to be tested; 3" marks are centered on the sample; 27 pound load applied vertically for 10 minutes. Percent stretch calculated as  $\frac{L_2 - L_1}{L_1} \times 100$ . Specimen relaxed for 10 minutes, percent residual set calculated using the same formula as before.

One sample was selected for Prototype submission from each project. Ten yards of each was knit, finished as before, and tested. The test results are listed below.

TABLE XII  
KNIT SEAT CUSHION FABRICS  
(Prototype - Projects 057, 058, 059)

<u>TEST/DESCRIPTION</u>	<u>5272-057 Sample 2</u>	<u>5272-058 Sample 2</u>	<u>5272-059 Sample 2</u>
Machine Type	Tricot	Raschel	Raschel
Number of Bars	2	2	2
Needles per Inch	20	24	24
Yarns used (F.B.)	200/100/3Z Nomex	40/1 Spun Nomex	200/100/3Z Nomex
(B.B.)	200/100/3Z Nomex	40/1 Spun Nomex	40/1 Spun Nomex
Quality (inches per 480 stitches)	14	14	14
Stitch Description	Reverse Jersey	Reverse Jersey (Stabilized)	Reverse Jersey
Construction (wales x courses)	25.5 x 34	29 x 35	25 x 38
Weight (oz/yd <sup>2</sup> )	8.3	7.3	7.6
Burst Strength (lbs.)	150+	150+	150+
Abrasion (Cycles to Destruct)	1800	1000	1580
Stretch (%) W x C	30 x 35	63 x 57	40 x 50
Set (%) W x C	3.3 x 1.7	6.7 x 13.3	3.3 x 6.7

## 2. RESEARCH SAMPLE, PROJECT 5272-074

Fabric 5272-057, sample 2, was selected by the Air Force for production run.

Two warps were prepared, each with 1120 ends of 200/100/3Z Nomex yarn, 56 inches wide. This width is not indicative of the working width of a tricot knitting machine, which is normally 84 inches.

The warps were threaded into a 2-bar, 20 gauge tricot machine and a one-yard head end was knitted using the following stitch:

Front bar - 1/2 1/0  
Back bar - 1/0 2/3

The head end was finished (scoured and heat set) and checked for construction. The construction was 26 x 33 and the weight was 8.2 ounces per square yard. This was within a reasonable tolerance of the 5272-057, sample #2 construction of 25.5 x 34 and 8.3 ounces per square yard.

A total of 204 yards of greige fabric was knit with 40 ends broken out during knitting. The cause for the broken ends was due to broken filaments from the yarn supplier which caught in the knitting element on the tricot machine and caused yarn breakage. This is considerably higher than normal for tricot knitting and is directly related to the quality of the producer's yarn. Consideration of this problem must be made in the "defect" section of the draft specification.

Finishing for the knit used the following procedure:

1. Scour open width on continuous scouring range at 160° F. in scouring solution of 1.0 g/l of TSP and detergent.
2. Dry at 300° F. to set construction.
3. Autoclave heat set using standard procedure for Nomex.
4. Pad on antistat solution: 6.6% Aston 123  
2.7% Accelerator EN  
pH - 6.5

Wet pick up at 50-60%.

5. Dry at 300° F., cure at 350° F. for 1.5 minutes.

Fabric overfed 9% in length.

The knitting machine conditions were as follows:

Yarn - 200/100/3Z Nomex, merge 1X071, Type 433  
Machine gauge - 20 (needles/inch)  
Number of bars - 2  
Threading - Full both bars  
Knitting width - 56"  
Knitting pattern - Front bar - 1/2 1/0  
Back bar - 1/0 2/3  
Knitting quality - 14" (per 480 stitches)  
Runner lengths - Front bar - 84.25"  
Back bar - 101"

The finished fabric was tested for physical properties and Table XIII compares those properties with the Development Sample, 5272-057, sample number 2.

TABLE XIII  
 KNIT SEAT CUSHION FABRICS  
 (Research Sample - Project 5272-074)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-074</u>	<u>5272-057 Sample #2</u>
Weight (oz/yd <sup>2</sup> )	5041	7.5	8.3
Construction (Wales x Courses)	5050	24.6 x 30.2	25.5 x 34
Burst Strength (lbs) (Ball Method)	5120	150+	150+
Stoll Abrasion (Cycles to Destruct) <sup>(1)</sup>	5302	1190	1800
Stretch (%: W x C)	(2)	29.2 x 63.4	30 x 35
Set (%: W x C)	(2)	4.0 x 6.0	3.3 x 1.7

(1) "0" emery paper, 3 psi diaphragm, 2 pound load.

(2) Test Procedure for stretch and set.  
 Specimen 9" x 3", long dimension to be tested; 3" marks are centered on the sample; 27 pound load applied vertically for 10 minutes. Percent stretch calculated as  $\frac{L_2 - L_1}{L_1} \times 100$ .  
 Relax specimen for 10 minutes, percent residual set calculated as before.

## SECTION VI

### FILAMENT CLOSURE TAPE

#### 1. PROTOTYPE DEVELOPMENT

The objective of this project was to produce a filament Nomex tape to substitute for MIL-T-8363, Type 1 Nylon. The use of this tape will be for closures on Life Vest equipment, etc. The technical objective was to make a tape with strength equal to the standard nylon with no change in width. The project proceeded in the following manner.

##### a. Project 5272-061

1.15 pounds of 200/100/0 Type 433 Nomex was twisted to three turns per inch "Z". This yarn was warped onto three beams and drawn single end per heddle according to the specification draft. Table XIV shows the physical properties of this tape.

The warps were redrawn doubling the number of ground ends. Various reedings were attempted on this draw to make a satisfactory tape, but the filling would not withstand the severe tension exerted by the double ground warp. No successful sample was made on this second draw. At this time, the warps had been used and a second project was initiated.

Finishing on all tapes tested consisted of a scour in boiling water with 1 g/l of TSPP and Alloscour TY; rinse and hang dry. Autoclave heat setting was not done on these items.

##### b. Project 5272-065

The balance of yarn prepared before was used for three warps. They were drawn into the loom as described in Table XIV, woven at 60 picks and tested. The results listed in Table XIV were satisfactory and this item was submitted as a prototype for the tapes. Figure 11 is a weaving specification sheet for this project.

TABLE XIV

## FILAMENT CLOSURE TAPE

(Prototype - Project 5272-061 &amp; -065)

<u>TEST</u>	<u>5272 061/1</u>	<u>5272 061/2*</u>	<u>5272 065<sup>(2)</sup></u>	<u>SPECIFI- CATION</u>
Thickness (inch)	0.030	-----	0.0365	0.030-0.040
Width (inch)	5/16	5/16	5/16	5/16 ± 1/32
Breaking Strength (lbs.)	273	435	373	350 (min.)
Weight (oz/yd)	0.135	*	0.16	0.08 (min.)
End in Warp				
Total	139	212	182	121 (min.)
Face and Back	87	160 (2 as 1)	138 (2 as 1)	84
Binder	22	22	16 (2 as 1)	16 (2 as 1)
Stuffer	30	30	28 (4 as 1)	21
Picks/Inch	76	60	62	60 (min.)
Denier and Ply				
All Warps	200 x 1	200 x 1	200 x 1	x 1
Filling	200 x 1	200 x 1	200 x 1	x 1
Twist per Inch				
All Warps	3.0	3.0	3.0	2.5 min.
Filling	3.0	3.0	3.0	2.5 min.

\* not checked

(2)

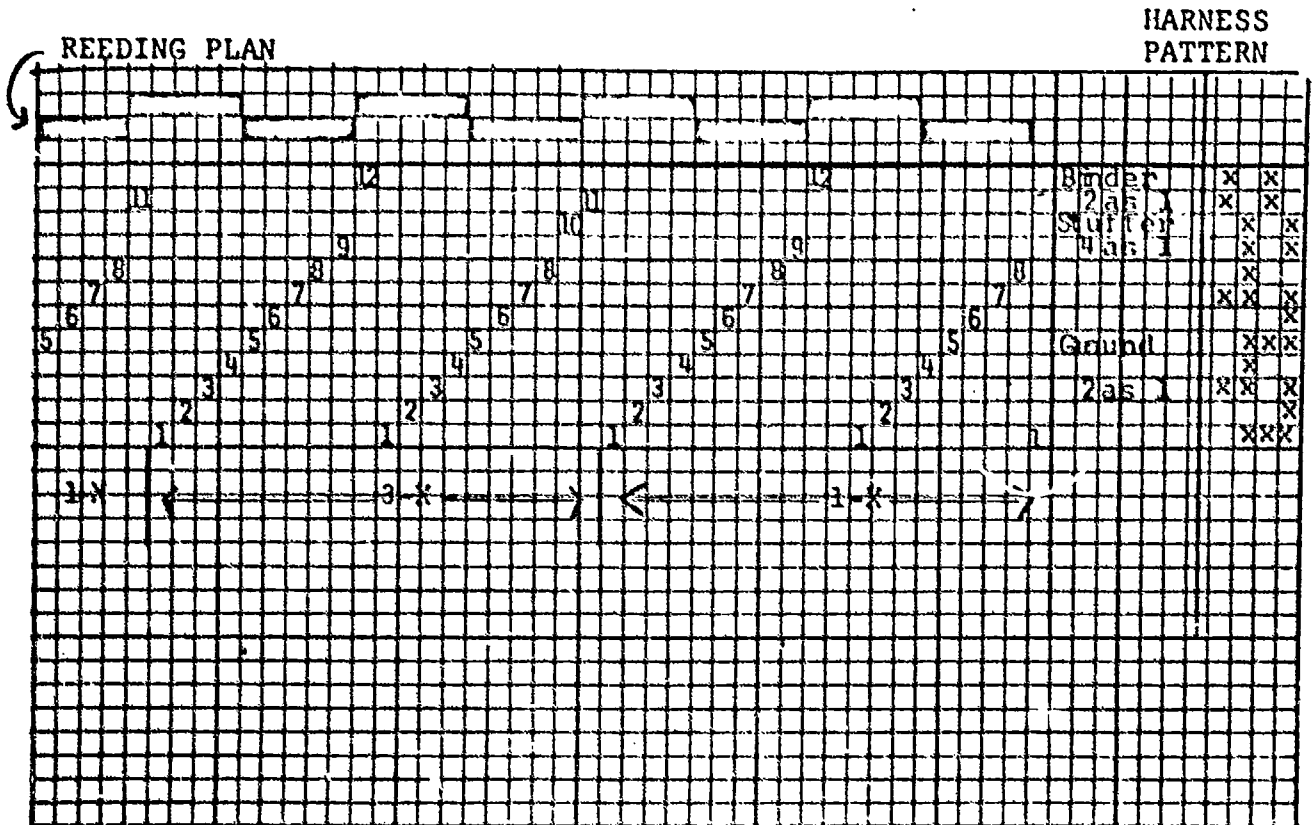
Prototype submitted

Figure 11

Fastener Tape - Project 5272-065

LOOM SETTING				OFF-LOOM DATA	
	BEAM 1	BEAM 2	BEAM 3		
Ends in Warp	138	28	16	Selvage	Ends Per Inch <u>182</u>
Reed No.	56			Yarn _____	Picks Per Inch <u>64</u>
Ends Per Dent	See Plan			_____ Each Side	Cloth Width _____
Reed Width	11/32				Take-up _____
Beams Used	3				Weight Per _____
Pick Wheel	64				Sq. Yd. <u>0.16 (oz.)</u>

Warp and Filling Yarns: 200/100/3Z Type 433



2. RESEARCH SAMPLE, PROJECT 5272-066

The contractor was authorized, via letter, to proceed with the 200 yards of tape to reproduce Project 5272-065.

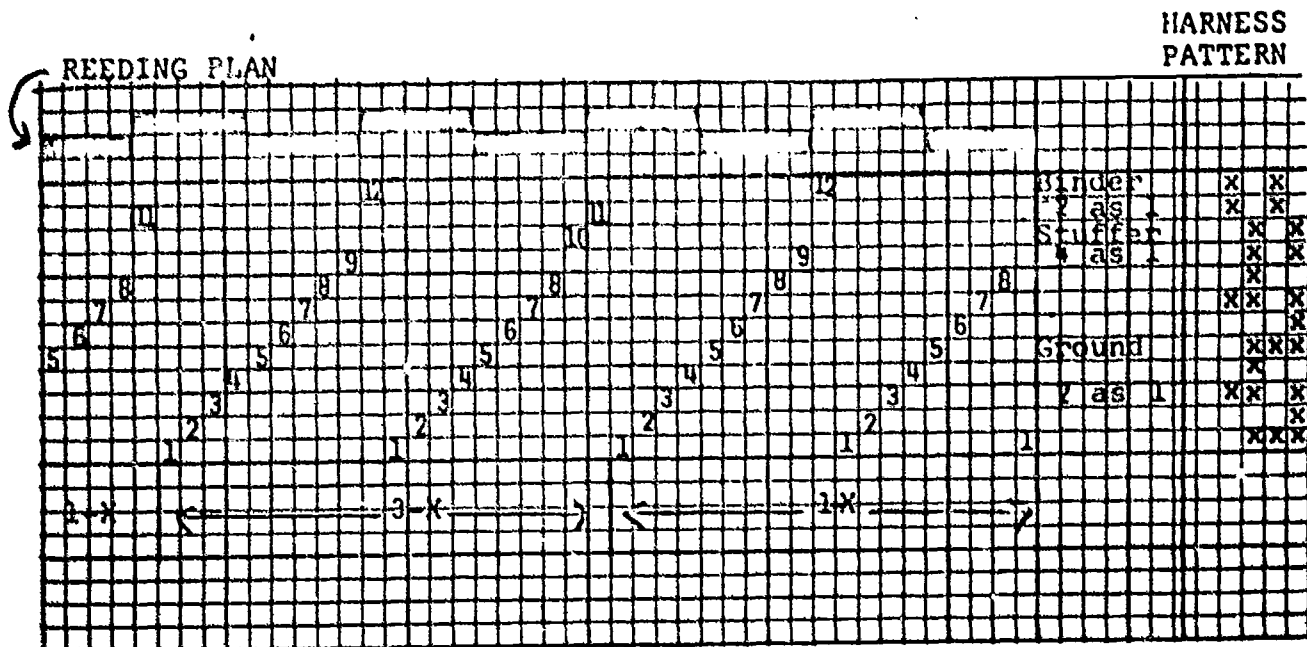
Project 5272-066 was assigned for the production and the tape was woven utilizing the loom set-up information as illustrated below.

Figure 12

Fastener Tape (Research Sample) - Project 5272-066

LOOM SETTING				OFF-LOOM DATA	
Ends in Warp	BEAM 1 138	BEAM 2 28	BEAM 3 16	Selvage	Ends Per Inch 182
Reed No.	56			Yarn _____	Picks Per Inch 64
Ends Per Dent	See Plan			_____ Each Side	Cloth Width _____
Reed Width	11/32				Take-up _____
Beans Used	3				Weight Per Sq. Yd. 0.16 (oz.)
Pick Wheel	64				

Warp and Filling Yarns: 200/100/38 Type 433



Finishing consisted of a scour in boiling water with 1 g/l of TSPP and Allo Scour TY; rinse and hang dry. Autoclave heat setting was not done on these items.

Twelve samples were tested for physical properties. The results are averaged and shown with the minimum and maximum on each variable test in the following table.

TABLE XV  
FILAMENT CLOSURE TAPE  
(Research Sample - Project 5272-066)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>RESULTS(1)</u>	<u>RANGE</u>
Thickness (inch)	5030	0.036	0.035-0.037
Width (inch)	5020	0.340	0.34-0.35
Breaking Strength (lbs.)	5100	366	359-376
Ends in Warp:	5050		
Total Count		182	None
Face and Back		138 (2 as 1)	None
Binder		16 (2 as 1)	None
Stuffer		28 (4 as 1)	None
Picks per Inch	5050	68	None
Denier and Ply	5050		
All Warps		200 d. x 1	None
Filling		200 d. x 1	None
Twist per Inch	4052		
All Warps		3.0	None
Filling		3.0	None

(1) Results from 12 samples.

## SECTION VII

### HARNESS WEBBING

#### 1. PROTOTYPE SAMPLE, PROJECT 5272-062

The objective of this development was to produce a Nomex webbing similar to MIL-W-17337, 2 inch, for use as life preserver harness and other webbing applications. Project number 5272-062 was assigned for this webbing development.

4.28 pounds of 1200/600/0 Type 430 Nomex was twisted to 2 tpi "Z". Two warps were made; 191 ends on the ground warp and 48 ends on the binder warp. A head end was woven at 42 picks and tested. The results are shown in Table XVI.

All critical factors were satisfactory, so the balance of the warp was woven out and finished as follows:

1. Scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP

at 180° F. for one-half hour.

2. Hang dry.
3. No autoclave heat set.

The sample was tested for verification and shipped as a prototype for this item. Figure 13 is a weaving data sheet for this webbing.

TABLE XVI  
HARNES WEBBING - 2 INCH  
(Prototype - Project 5272-062)

<u>TEST</u>	<u>UNFINISHED HEADEND</u>	<u>FINISHED PROTOTYPE</u>	<u>SPECIFI- CATION</u>
Thickness (inch)	0.060	0.060	None
Width (inch)	2.0	2.0	2 ± 1/16
Breaking Strength (lbs.)	2250	2198	2200 (min.)
Weight (oz/yd.)	1.64	1.76 .	1.42 (max.)
<b>Ends in Warp</b>			
Total Count	237	237	238 (min.)
Ground	191	191	192
Binder	46	46	46
Picks per Inch	47	47	48 (min.)
<b>Denier and Ply</b>			
All Warp	1200 x 1	1200 x 1	840 x 1
Filling	1200 x 1	1200 x 1	840 x 1
<b>Twist per Inch</b>			
All Warp	2	2	N. A.
Filling	2	2	N. A.

Figure 13

Harness Webbing - 2 Inch - Project 5272-062

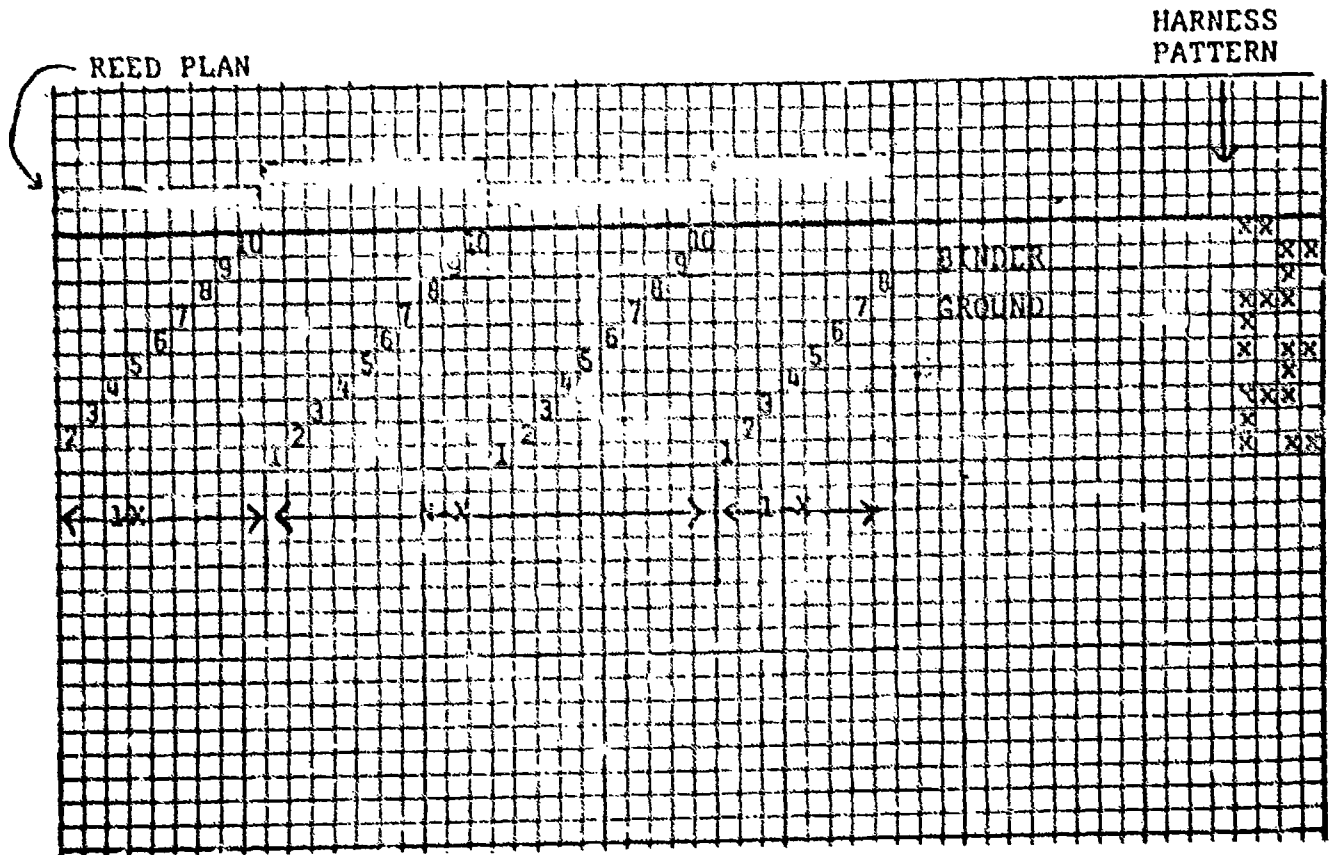
LOOM SETTING

	BEAM 1	BEAM 2	BEAM 3	Slvage
Ends in Warp	191	48		Yarn _____
Reed No.	12			_____ Each Side
Ends Per Dent	See Plan			
Reed Width	_____			
Beams Used	_____			
Pick Wheel	42			

OFF-LOOM DATA

Ends Per Inch	239
Picks Per Inch	44
Cloth Width	2"
Take-up	_____
Weight Per Sq. Yd.	1.76

Warp and Filling Yarns: 1200/600/2Z Nomex Type 480



2. RESEARCH SAMPLE PRODUCTION, PROJECT 5272-067

The same letter authorizing production of webbing also included a request to change the requirement for the webbing from 2 to 1 1/2". The contractor interpreted this to mean a reproduction of the weave and construction as submitted in 5272-062, but to reduce the number of ends so that the webbing would be 1 1/2" wide.

Project 5272-067 was assigned for the production of research samples of 1 1/2" Nomex webbing. A head end was taken from each position and tested for strength to see that it conformed to the requirements of the Specification No. MIL-W-17337B. The strength was acceptable and weaving was approved.

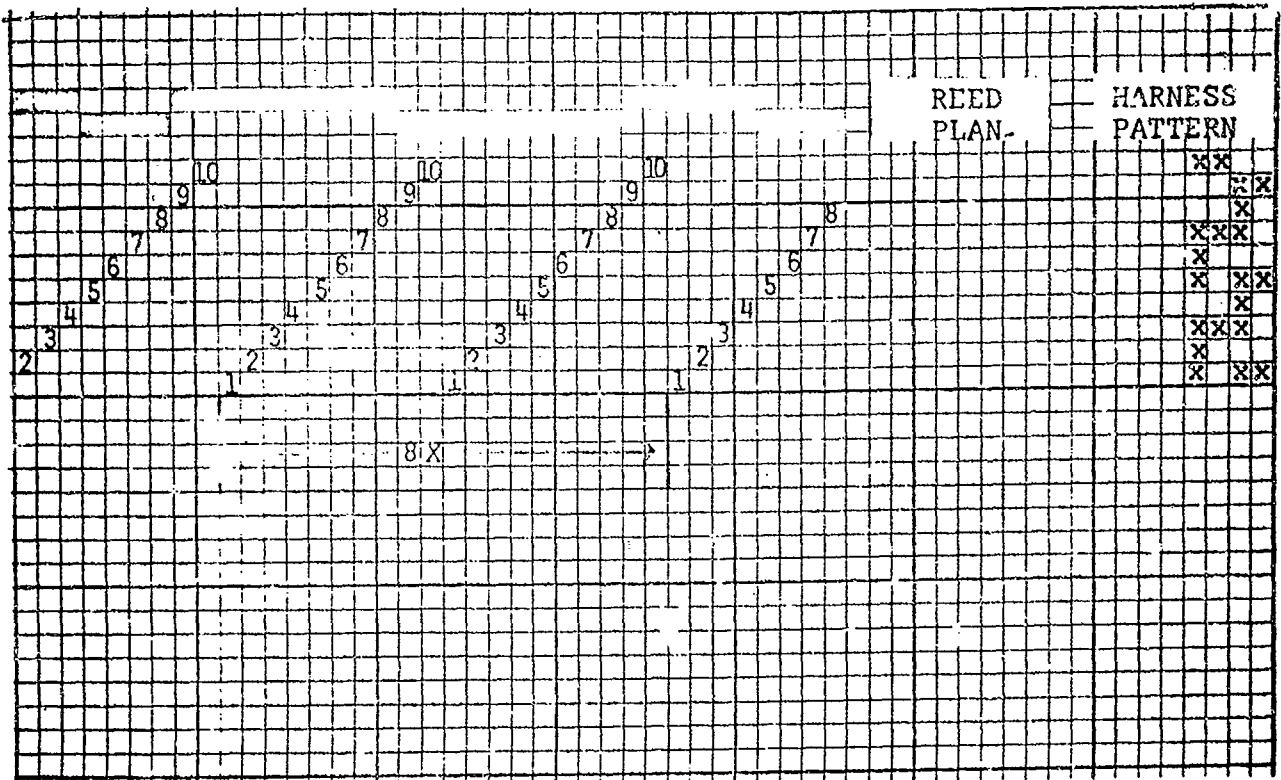
Figure 14 is a fabric data sheet showing construction details for the research sample.

Figure 14

Harness Webbing - 1 1/2 Inch - Project 5272-067

LOOM SETTING				OFF-LOOM DATA		
	BEAM 1	BEAM 2	BEAM 3	Selvage	Ends Per Inch	<u>170</u>
Ends in Warp	144	34		Yarn _____	Picks Per Inch	<u>47</u>
Reed No.	<u>11.5</u>			_____ Each Side	Cloth Width	<u>1 1/2"</u>
Ends Per Dent	<u>See Plan</u>				Take-up	_____
Reed Width	<u>1 1/2 + 1/16</u>				Weight Per	_____
Beams Used	<u>2</u>				Sq. Yd.	_____
Pick Wheel	_____					
Shuttle Springs - 6 + 7 Over the bridge						

Warp Yarn: 1200/600/23 Natural Nomex T-430 Merge 17573



A total of 243 yards was produced. Finishing consisted of a scour in 180° F. water with 1 g/l of TSPP and Allo Scour TY; rinse and hang dry. Autoclave heat setting was not done. The webbing was inspected and samples were taken at random.

Ten samples were tested for physical properties. The results are averaged and shown, with the minimum and maximum on each variable test reported.

TABLE XVII  
HARNESS WEBBING - 1 1/2 INCH  
(Research Sample - Project 5272-067)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>RESULTS<sup>(1)</sup></u>	<u>RANGE</u>
Thickness (inch)	5030	.058	.057 - .061
Width (inch)	5020	1.53	1.50 - 1.56
Breaking Strength (lbs.)	5100	1.846	1.725 - 1.925
Weight (oz/yd <sup>2</sup> )	5040	1.292	1.278 - 1.316
Ends in Warp:	5050		
Total Count		177	None
Ground		143	None
Binder		34	None
Picks per Inch	5050	47	None
Denier and Ply	5050		
All Warp		1200 d. x 1	None
Filling		1200 d. x 1	None
Twist per Inch	4052		
All Warp		2 Z	None
Filling		2 Z	None

---

(1) Results from 10 samples.

## SECTION VIII

### FLIGHT CLOTHING OUTER FABRIC

#### 1. PROTOTYPE DEVELOPMENT, PROJECT 5272-064

Design objectives of this project were a Nomex staple fabric (because of high volume usage), medium weight, wind resistance, and pleasing aesthetics. Development efforts for low permeability staple fabrics have shown an opposition between low air permeability and aesthetics.

A warp was prepared (24 inches wide) using 50/1 Nomex yarns at a construction of 180 ends per inch for 4320 total ends. This was drawn in on 12 harness in a skip draw and reeded at 4 ends per dent in a 45 dent reed and placed in a narrow silk loom for weaving three samples; Sample #1 -  $\frac{2}{1}$  twill; Sample #2 -  $\frac{3}{1}$  twill; Sample #3 - 4 harness Satin. 2  
All samples were woven at 78 picks per inch, finished as follows:

1. Scour with 2.0 g/l Allo Scour TY  
2.0 g/l TSPP

Run at 210° F. for 1/2 hour and rinse until clear.

2. Autoclave Nomex cycle.
3. Apply Zepel-Stannex finish:

Solution: 5.0% DDI  
0.5% Igepal CO 630  
1.7% Zepel B  
13.4% Stanax

4. Pad, dry at 250° F. and cure at 350° F. for 3 minutes.

TABLE XVIII  
 FLIGHT CLOTHING OUTER FABRIC  
 (Prototype - Project 5272-064)

<u>TEST</u>	<u>Sample No. 1</u>	<u>Sample No. 2</u>	<u>Sample No. 3</u>
Yarns/inch warp x filling	184 x 83	183 x 81	184 x 81
Weight ounces/yd <sup>2</sup>	4.30	4.26	4.22
Breaking Strength (lbs.) Grab Method warp x filling	229 x 88	221 x 85	225 x 89
% Elongation @ Break warp x filling	50 x 26	52 x 26	48 x 28
Tearing Strength (lbs.) Tongue Method warp x filling	10 x 7	11 x 9	11 x 8
*Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.) at 0.5" water pressure	148	187	153

\* Fabrics were not calendered.

The warp was re-reeded at a 40 dent reed, 5 ends per dent for 200 ends per inch. This was an increase of 20 ends per inch over the original samples. Two samples were woven; numbered 4 and 7. Nine yards of fabric were woven as Sample 4, utilizing the  $\frac{3}{1}$  twill weave as in Sample 2, and the balance of the  $\frac{2}{5} \frac{1}{4}$  warp (4 1/2 yards) was woven with a  $\frac{2}{5} \frac{1}{4}$  twill for a more pronounced surface effect.

Figure 15 is a copy of the fabric specification sheet.

Figure 15

Flight Clothing Outer Fabric (Project 5272-064)

LOOM SETTING

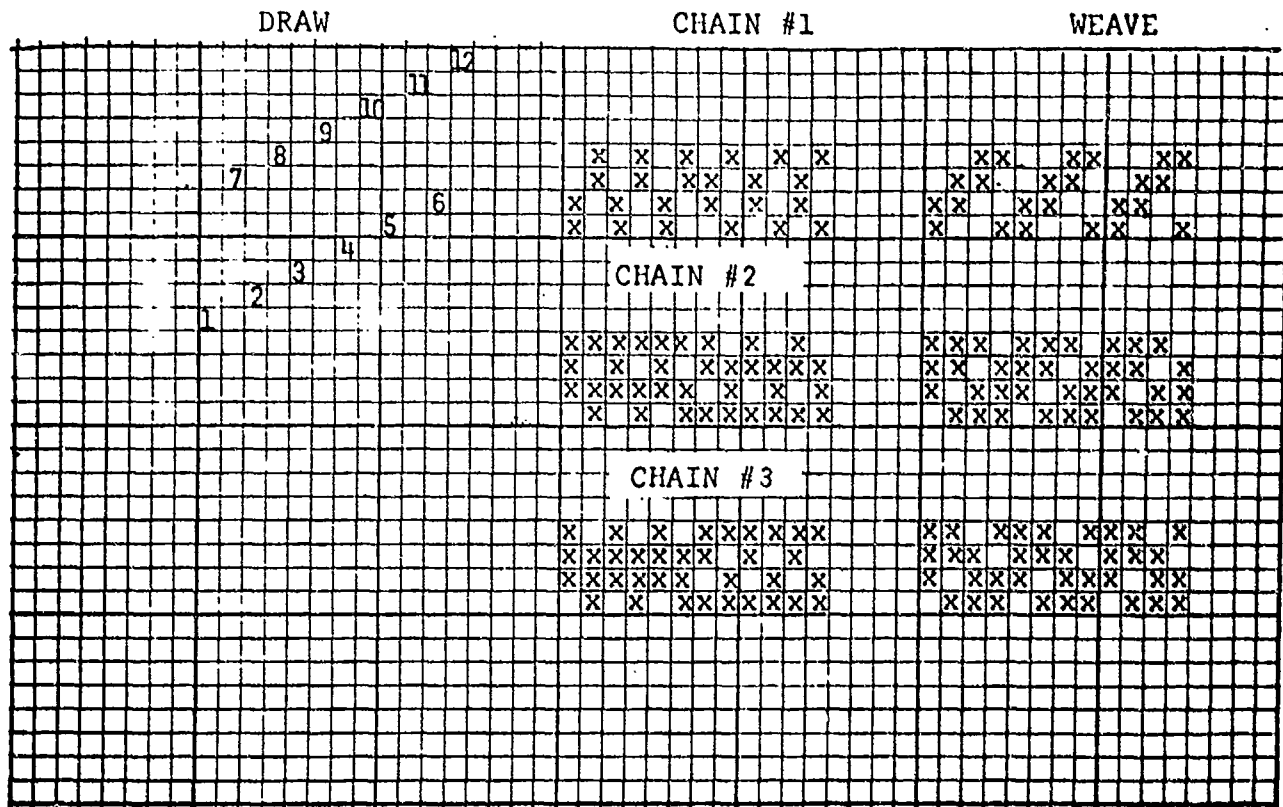
	BEAM 1	BEAM 2	BEAM 3
Ends in Warp	4320		
Reed No.	45		
Ends Per Dent	4		
Reed Width	24		
Beams Used			
Pick Wheel			

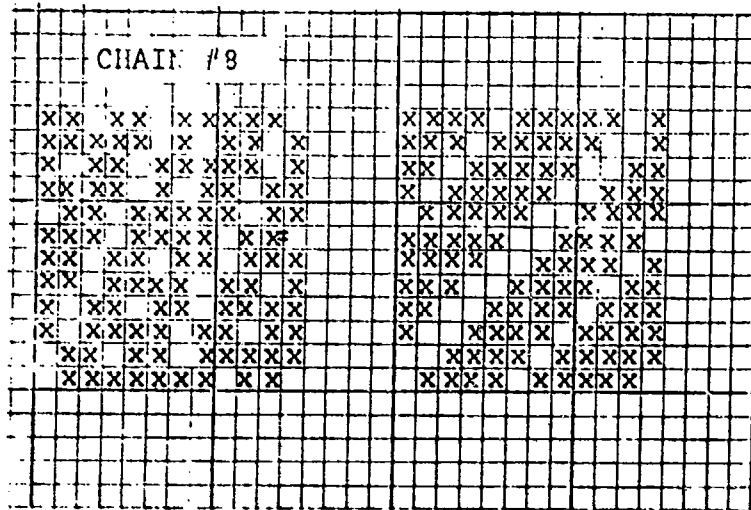
Selvage  
Yarn 12 Doubles  
Each Side

OFF-LOOM DATA

Ends Per Inch	_____
Picks Per Inch	_____
Cloth Width	_____
Take-up	_____
Weight Per Sq. Yd.	_____

Warp and Filling Yarns: 50/1 Nomex, Type 452





SAM.	DR #	HC #	RC #	PX	PX MI	WEAVE INSTS.	WOVEN DATE	BY	O.K.	BOX 1
1	1	1	\$ol.	78		HE" 36 YDS. YDS.				50/1 Nomex Type 452
2	1	2	\$ol.	78		HE" 36 YDS. YDS.				50/1 Nomex Type 452
3	1	3	\$ol.	78		HE" 36 YDS. YDS.				50/1 Nomex Type 452
RE-RELD TO 40 DENT/5 P						HE" 36 YDS.				
4	1	2	\$ol.	78		HE" 36 YDS. 9 YDS.				50/1 Nomex Type 452
7	1	8	\$ol.	90		HE" 36 YDS. W.O. YDS.				50/1 Nomex Type 452

The finishing on these fabrics included, in addition to the scour and autoclave, a three-pass calender of the face side at 350° F. and 11 tons pressure, followed by a beam scour at 230° F. for 1 hour to soften the hand.

The fancy twill, fabric #7, was neither tested nor submitted to the Air Force. Table XIX compares 5272-064, sample #4, with the filament specification fabric properties.

TABLE XIX  
FLIGHT CLOTHING OUTER FABRIC  
(Prototype - Project 5272-064)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>Sample #4</u>	<u>SPECI- FICATION</u>
Weight (oz/yd <sup>2</sup> )	5041	4.1	5.4
Breaking Strength (lb.) W	5100	250	150
F		80	160
Tearing Strength (lbs.) W	5134	8	7
F		7	7
Thread Count (W x F)	5050	204 x 84	250 x 78
Elongation @ Break % W	5100	48	20
F		30	20
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	56*	10

\* Fabric was calendered.

## 2. PROTOTYPE DEVELOPMENT, PROJECT 5272-063

Project no. 5272-063 was initiated to produce a twill fabric closer in weight to MIL-C-4294, Type III fabric, 5.40 ounces per square yard, than 5272-064, sample 4.

Using the compact cover factor for polyesters and Nomex, the cover for fabric 5272-064, sample 4, was calculated. The following equations were used for this computation:

Fabric Cover Calculations

26.8 = ccf for polyesters and Nomex

$$\frac{\text{Yarns/Inch}}{26.8 \sqrt{\text{cotton count}}} = \% \text{ cover}$$

$$26.8 \sqrt{\text{cotton count}}$$

5272-064, #4  
(warp)

$$\frac{200}{26.8 \sqrt{50}} = 107\%$$

(filling)

$$\frac{78}{26.8 \sqrt{50}} = 41.5\%$$

For 40/1 yarn at equivalent cover -

$$26.8 \times \frac{\sqrt{40}}{\sqrt{50}} \times 107 = 182 \text{ ends}$$

$$26.8 \times \frac{\sqrt{40}}{\sqrt{50}} \times 41.5 = 72 \text{ picks}$$

Further calculation was required to determine if a construction of 182 x 72 was sufficient for a 5.4 ounce weight. This calculation was done using the following formula:

#### Fabric Weight Calculation

$$\text{Weight (oz/yd}^2\text{)} = \frac{\text{Warp} \times 36 + \text{fill} \times 36}{840 \times \text{cotton count}} \times 1.10 \text{ (crimp)} \times 16$$

$$\text{Weight of 182} \times 72 = \frac{6560 \times 2600}{33000} \times 1.10 \times 16 = 4.85 \text{ oz.}$$

$$\begin{array}{l} \text{Construction should} \\ \text{be 200} \times 80 = \end{array} \frac{7,300 + 2,900}{3300} \times 1.10 \times 16 = 5.40 \text{ oz.}$$

Accordingly, a warp was prepared using 40/1 Nomex; at a construction of 200 ends per inch. This warp was prepared long enough to allow sufficient fabric for calendering to achieve the lustrous surface.

The warp was drawn into a skip-draw on 20-harness so that both a 4-shaft and 5-shaft weave would be made. It was anticipated that a 5-shaft weave would be necessary in order to accomplish the 80-pick construction.

Two samples were prepared; sample one, a 3 right-hand twill and sample two, a 4 right-hand twill. Table XX lists the finished I (not calendered) head end properties of these two samples.

Both samples were finished according to the following procedure:

1. Jig scour with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
at 180° F. for one-half hour.
2. Dry.
3. Autoclave using Nomex heat set procedure.
4. Semi Decate to smooth fabric;  
2 minutes steam, 3 minutes air

TABLE XX  
 FLIGHT CLOTHING OUTER FABRIC  
 (Prototype - Project 5272-063)

<u>TEST</u>	<u>Sample #1</u>	<u>Sample #2</u>	<u>CCC-T-191b METHOD</u>
Yarns/inch (W x F)	204 x 82	205 x 88	5050.1
Weight (oz/yd <sup>2</sup> )	4.95	5.40	5041
Breaking Strength (lbs.) (W x F)	296.0 x 100.0	313.0 x 108.0	5100
Elongation at Break (%) (W x F)	53.0 x 28.0	57.0 x 30.0	5100
Tearing Strength (lbs.) (W x F)	11.0 x 7.0	11.0 x 8.0	5134
*Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	96.4	100	5450

\* Fabrics were not calendered.

Sample number 2 was selected for weaving 20 yards long for further finishing and treating with a water repellent.

Figure 16

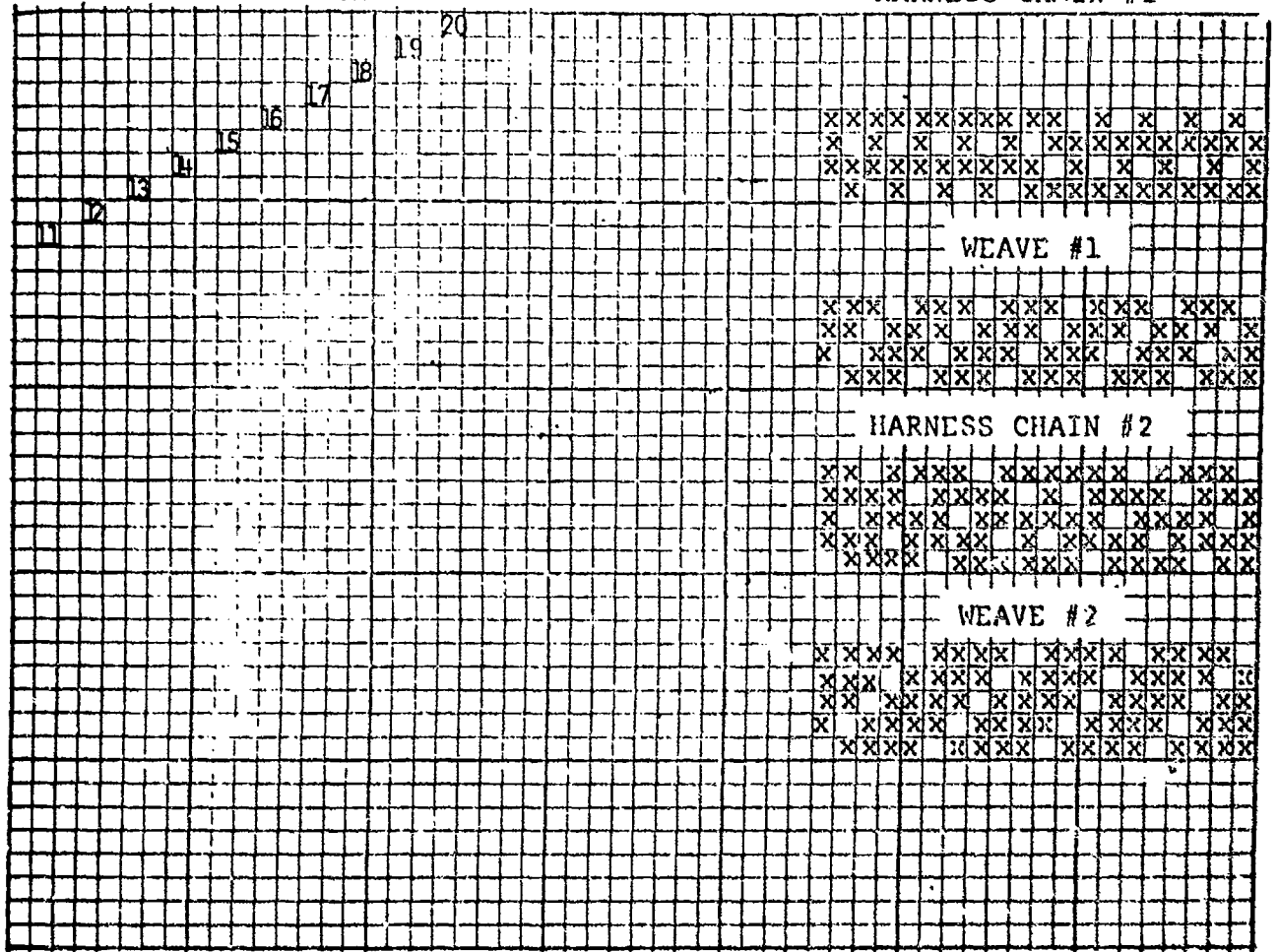
Flight Clothing Outer Fabric (Project 5272-063)

LOOM SETTING				OFF-LOOM DATA		
	BEAM 1	BEAM 2	BEAM 3	Selvage	Ends Per Inch	205
Ends in Warp	3408			Yarn _____	Picks Per Inch	88
Reed No.	33.3			_____ Each Side	Cloth Width	16.4"
Ends Per Dent	6				Take-up	12.8%
Reed Width	17				Weight Per	
Beams Used	1				Sq. Yd.	5.4
Pick Wheel	78					

Warp and Filling Yarns: 40/1 Nomex, Type 452

DRAWING DRAFT

HARNESS CHAIN #1



SAM.	DR #	HC #	BC #	PX	PX MI	WEAVE INSTS.	NOVEN DATE	BY	O.K.	BOX 1
1	1	1		72		HE" 18 YDS.				40/1 Nomex Type 452
1	1	2		78		HE" 18 YDS. W.O. YDS.				40/1 Nomex Type 452

The fabric was finished according to the following procedure:

1. Jig scour at the boil to remove sizing.
2. Autoclave heat set to stabilize fabric.
3. Calender 300° F., two passes each face,  
11 tons pressure.
4. Pad on mixture of:
  - 5.0% Di Isocyanate 1410
  - 0.5% Igepal CO 630
  - 13.0% Zepel B
5. Dried and cured at 350° F. for three minutes.

The water repellent treatment was not as successful as should have been because the Di Isocyanate precipitated out of solution during padding and created the spots or marks on the fabric.

TABLE XXI  
FLIGHT CLOTHING OUTER FABRIC  
(Prototype - Project 5272-063)

TEST	CCC-T-191b METHOD	Sample #2		SPECI- FICATION
		HEAD END	FINISHED (1)	
Weight (oz/yd <sup>2</sup> )	5041	5.4	5.2	5.4
Breaking Strength (lbs.) (W x F)	5100	313 x 108	326 x 110	150 x 160
Tearing Strength (lbs.) (W x F)	5134	11 x 18	13 x 9	7 x 7
Thread Count (W x F)	5050	205 x 88	210 x 91	250 x 78
Elongation at Break (%) (W x F)	5105	53 x 28	49 x 33	20 x 20
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	100	23	10

(1) Calendered and water repellent treated.

3. PROTOTYPE SAMPLE, PROJECT 5272-060

A revision of sample 5272-063, sample 2, was initiated. It was to be basically the same construction (200 x 76) as previously, using a 40/1 Nomex yarn in warp and filling. A different reed-  
ing pattern was used for this fabric placing 5 ends in a dent  
instead of 6 ends per dent.

Three fabrics were prepared and submitted to the Government for  
evaluation as candidate materials for flight clothing outer fabric.  
The three fabrics were variations of a five-harness weave design.  
Sample number 1 was a 4 left-hand twill, sample number 2 was  
a 4 right-hand twill 1 and sample number 3 was a five-  
I harness satin.

Eight yards each of the three samples were woven in one piece.  
The piece was finished according to the following procedure:

1. Scour on jig with 1.0 g/l Allo Scour TY  
1.0 g/l TSP  
  
Run at 160° F. and rinse.
2. Dry.
3. Autoclave heat set, using Nomex cycle.
4. Dry.
5. Semi Decate 2 minutes steam, 2 minutes air.
6. Calender at 350° F./6 tons pressure, overfeed  
smooth rool on warp face.
7. Apply Zepel water repellent;  
  
Solution: 5.0% DDI  
0.5% Igepal CO-630  
1.7% Zepel B  
  
Pad finish onto fabric and dry.
8. Cure at 350° F. for three minutes.

The fabrics were tested after finishing and submitted to the  
Government for further evaluation. Table XXII lists the physical  
properties of the three samples as submitted to the Government.

Figure 17

Flight Clothing Outer Fabric (Project 5272-060)

LOOM SETTING

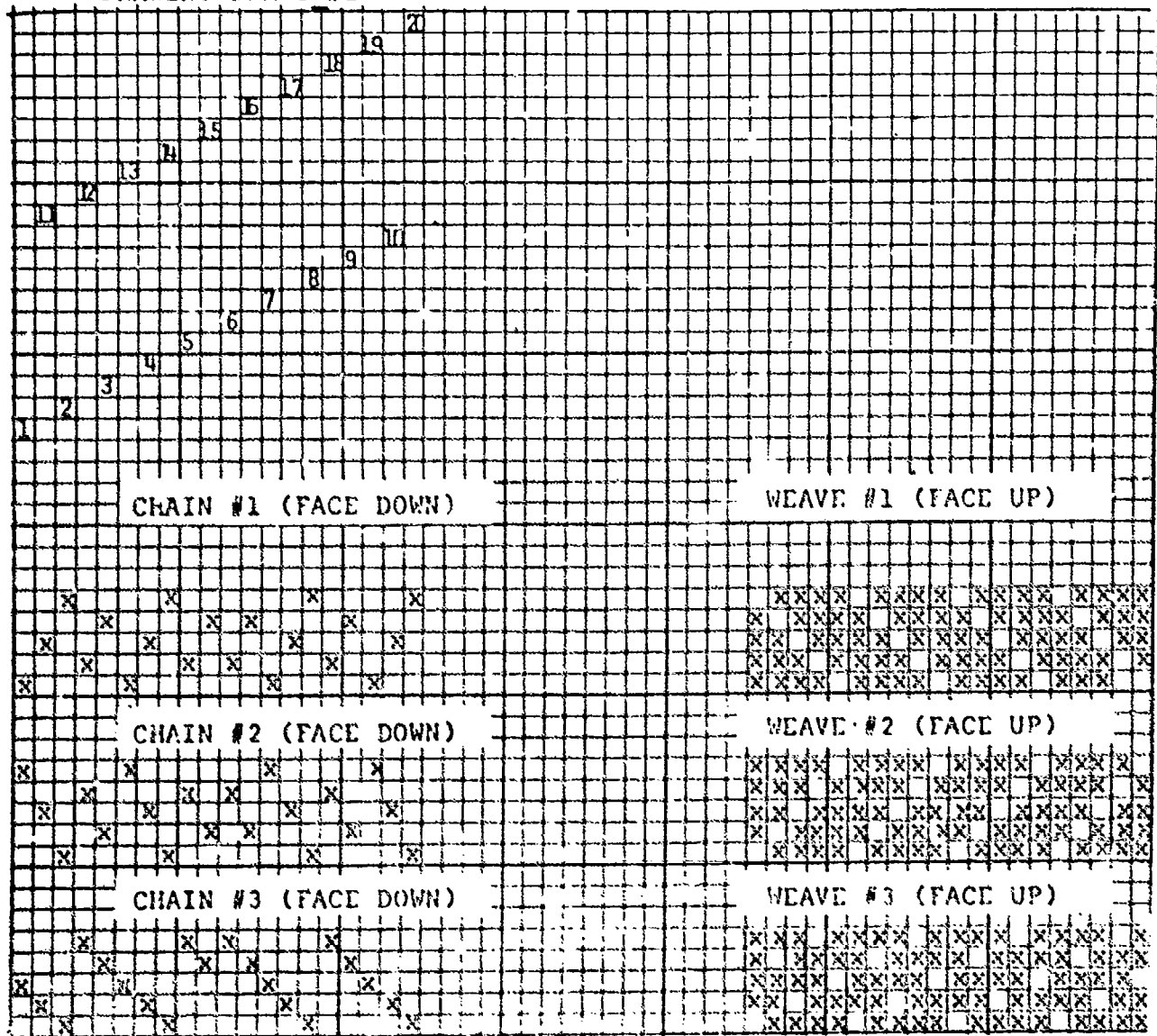
OFF-LOOM DATA

	BEAM 1	BEAM 2	BEAM 3
Ends in Warp	4800		
Reed No.	40		
Ends Per Dent	5		
Reed Width	24"		
Beams Used	1		
Pick Wheel			

Selvage	_____
<u>Catch</u>	_____
<u>Cord</u> Each Side	_____
Ends Per Inch	_____
Picks Per Inch	_____
Cloth Width	_____
Take-up	_____
Weight Per	_____
Sq. Yd.	_____

Warp and Filling Yarn: 40/1 Sage Green Nomex T-452 4.75 T.M.

DRAWING DRAFT #1



SAM.	DR #	HC #	BC #	PX	PX WH	WEAVE INSTS.	WOVEN DATE	BY	O.K.	BOX I	
1	1	1	Sol.	78	76	HE" 18				40/1 Sage Green T-452 Nomex	4.75 T.M.
						YDS. 8					
						YDS.					
2	1	2	Sol.	78	76	HE" 18				40/1 Sage Green T-452 Nomex	4.75 T.M.
						YDS. 8					
						YDS.					
3	1	3	Sol.	78	76	HE" 18				40/1 Sage Green T-452 Nomex	4.75 T.M.
						YDS. 8					
						YDS.					

TABLE XXII

FLIGHT CLOTHING OUTER FABRIC

(Prototype - Project 5272-060)

TEST	CCC-T-191b METHOD	5272-060 Sample 1	5272-060 Sample 2	5272-060 Sample 3
Weight (oz/yd <sup>2</sup> )	5041	5.46	5.33	5.35
Breaking Strength (lbs.: W x F)	5100	179 x 63	181 x 67	175 x 70
Tearing Strength (lbs.: W x F)	5134	15 x 9	15 x 11	16 x 10
Thread Count (W x F)	5050	200 x 85	207 x 81	208 x 82
Elongation at Break (%: W x F)	5100	44 x 23	44 x 25	42 x 28
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	26	27	31
Spray Rating	5526	80	70	90

4. RESEARCH SAMPLE PRODUCTION, PROJECT 5272-073

Sample 5272-060, sample 1, was selected by the Air Force for Research Sample production. A warp was prepared on two beams each with 5,004 ends for a total of 10,008 in the warp. This was done to reduce crowding and running problems during warping because of the high construction of the warp. The warp was set up in an MP-loom at a construction of 200 x 78.

5. FLIGHT CLOTHING OUTER FABRIC, PROJECT 5272-073

A head end was woven at an in-loom construction of 200 x 78. This sample was scoured and checked for construction, which was 208 x 88. This construction appeared within a reasonable tolerance of the development sample (5272-060, sample 1), which was 200 x 85.

The fabric in-loom specifications are as follows:

Figure 18

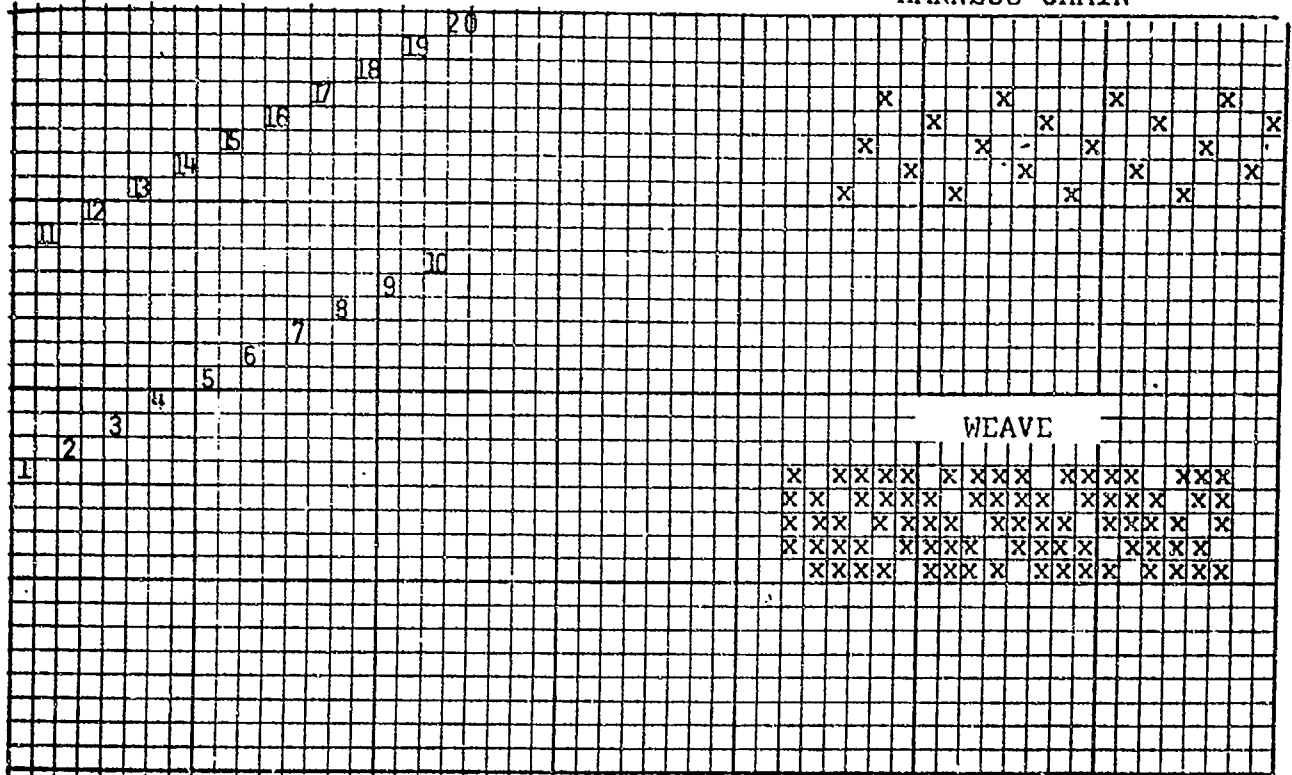
Flight Clothing Outer Fabric (Project 5272-073)

LOOM SETTING			OFF-LOOM DATA			
	BEAM 1	BEAM 2	BEAM 3	Selvage	Ends Per Inch	_____
Ends in Warp	5004	5004		Yarn _____	Picks Per Inch	_____
Reed No.	40			_____ Each Side	Cloth Width	_____
Ends Per Dent	5				Take-up	_____
Reed Width	50"				Weight Per	_____
Beams Used	2			CATCH CORD	Sq. Yd.	_____
Pick Wheel						

Warp and Filling Yarns: 40/1 Nomex 4.75 T.M. Sage Green Type-452

DRAWING DRAFT

HARNES CHAIN



SAM.	DR #	HC #	BC #	PX	PX MI	WEAVE INSTS.	WOVEN DATE	BY	O.K.	BOX 1
1	1	1	Sol.	78		HE" 36				
						YDS. W.O. 173 yds.				
						YDS.				

The fabric was finished according to the following procedure:

1. Scour open width on continuous scouring range at 160° F. in scouring solution of 1.0 g/l of TSP and detergent.
2. Dry at 300° F. to set construction.
3. Autoclave heat set using standard procedure for Nomex.
4. Pad on antistat solution: 6.6% Aston 123  
2.7% Accelerator EN  
pH - 6.5

Wet pick up - 50-60%.

5. Dry at 300° F., cure at 350° F. for 1.5 minutes.
6. Calender 2 passes through a "friction" calender. Operating temperature, 360° F. Overfeed on smooth, steel roll of 10%; pressure - 40 tons.

The finished fabric was tested for physical properties. Those properties are shown in Table XXIII in comparison with fabric 5272-060, sample 1, which was the prototype item for this fabric.

TABLE XXIII

FLIGHT CLOTHING OUTER FABRIC

(Research Sample - Project 5272-073)

<u>TEST</u>	<u>CCC-T-191b METHOD</u>	<u>5272-073</u>	<u>5272-060 Sample #1</u>	<u>SPECI- FICATION</u>
Weight (oz/yd <sup>2</sup> )	5041	5.45	5.46	5.4
Thread Count (W x F)	5050	206 x 83	179 x 63	150 x 160
Breaking Strength (lbs.: W x F)	5100	305 x 98	200 x 85	250 x 78
Elongation @ Break (%: W x F)	5100	60 x 28	44 x 23	20 x 20
Tearing Strength (lbs.: W x F)	5134	10 x 14.5	15 x 9	7 x 7
Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	5450	28.9	26	10

## SECTION IX

### CONCLUSIONS

As a result of this program, we have drawn the following conclusions:

1. Generally, the fabrics developed had equal or better physical properties compared to the specifications of those fabrics they were designed to replace.
2. Mock leno (3 x 4) weave did not improve fabric properties over the (3 x 3) basket weave.
3. Using a 24/1 instead of a 50/2 in the Anti-G-Suit (5.5 oz/yd<sup>2</sup>) fabric will result in a savings of \$0.28 to \$0.29 per lineal yard.
4. The exact cause of an increase in tearing strength on the Anti-G-Suit fabric was not determined. Possible reasons could be production finishing, adding antistat, changing twist in the yarn.
5. Cast coating onto heavy duck fabric resulted in a stiff material.
6. Calender coating results in a "soft" finish, but adds a large amount of weight.
7. Equivalent weight filament knit fabrics exhibit superior abrasion to staple knit fabrics.
8. Filament Nomex is not currently produced in a quality that would allow large scale high speed warp knitting.
9. A staple fabric can be rendered aesthetically pleasing by constructing it with a high warp count, and polishing the warp face with a calender.
10. A warp of 200 ends per inch of 40/1 Nomex has questionable running properties.
11. Consistency of test results was not of a level that would lend a great deal of confidence to large-scale production of any fabrics, without first conducting a scale-up run.
12. Addition of available commercial water repellents increases the flammability of the Nomex fabrics to an unacceptable level.

## SECTION X

### RECOMMENDATIONS

Based on the conclusions drawn, we make the following recommendations:

1. Other fabric specifications that may present a burning hazard, should be evaluated for possible replacement by Nomex.
2. A definitive study be conducted, evaluating twist, finishes, and procedures regarding their effect on tearing strength of the Anti-G-Suit fabric.
3. Further development be conducted to substantially reduce the weight add-on of Hypalon for the Life Preserver Cover.
4. That the Air Force examine the possibilities of adopting warp knit fabrics into other areas in addition to seat cushion covers.
5. The Flight Clothing Outer Fabric should be refined further for commercial running.
6. Any fabric produced, and specification written, should undergo a "scale-up" verification run before a large purchase is made.
7. Alternate approaches to applying water repellents should be investigated, specifically spraying, coating and blocking.

APPENDIX I  
CONTRACT ADMINISTRATION  
PROJECT CONTROL

<u>5272 #</u>	<u>Item #</u>	<u>Description</u>
052	I	Administrative and Material charges
053	I	Anti-G-Suit from 50/2 yarn
054	II & III	Administrative, material and data charges
055	I	Seat cushion, armor vest, and other
056	I	Anti-G-Suit from 24/1 yarn
057	I	Filament tricot seat cushion cover
058	I	Staple raschel seat cushion cover
059	I	Combination raschel seat cushion cover
060	I	Redo of 40/1 flight clothing outer fabric
061	I	Filament tape first prototype
062	I	Filament webbing prototype
063	I	Flight clothing outer fabric from 40/1 yarn
064	I	Flight clothing outer fabric from 50/1 yarn
065	I	Filament tape second prototype
066	II	Filament tape research sample
067	II	Filament webbing research sample
068	I	Life preserver cover - Incopa
069	I	Life preserver cover - Du Pont
070	II	Anti-G-Suit research sample
071	II	Seat cushion, armor vest research sample
072	II	Life preserver cover research sample
073	II	Flight clothing outer fabric research sample
074	II	Knit seat cushion research sample

## APPENDIX II

### Standard Autoclave Heat Set Procedure Used on Nomex Fabrics.

1. Carefully roll cloth onto wooden shell wrapped with leader cloth.
2. Autoclave set w/30 psi dry steam as follows:
  - 5 minutes pre-vacuum to 20 inches mercury
  - 20 minutes steam @ 30 psi
  - 5 minutes vacuum
  - 20 minutes steam @ 30 psi
  - 5 minutes vacuum
  - Exhaust to air.
3. Fabric may need additional drying if autoclaving is final step.

APPENDIX III

MATERIALS (YARN)

Item	Project #	P. O.	Vendor	POUNDS		
				ord'd.	rec'd.	used
200/100/0 Sage Green	057, 059, 061, 065, 066	9143	E. I. du Pont	50	50	50
1200/600/0 Natural	062	9143	E. I. du Pont	10	11	11
20/1 Type 452	Optional	9169	China Grove	10	10	0
20/2 Type 452	055	9169	China Grove	30	30	30
30/1 Type 452	Optional	9169	China Grove	10	10	0
30/2 Type 452	Optional	9169	China Grove	15	16	0
40/1 Type 452	058, 059	9169	China Grove	15	13	13
40/2 Type 452	Optional	9169	China Grove	10	9	0
50/1 Type 452	064	9169	China Grove	17	15	15
50/2 Type 452	053	9169	China Grove	10	16	16
1200/600/0 Natural	067	9420	E. I. du Pont	20	17	17
1200/600/0 Natural	067	9449	E. I. du Pont	15	15	15
25/1 Type 452 Spun	056	9657	China Grove	10	10	10
40/1 Type 452 Spun	063	9657	China Grove	10	10	10
200/100/0 Sage Green	074	10107	E. I. du Pont	150	151	151
40/1 Type 452 Spun	073	10106	China Grove	100	104	104
24/1 Type 452 Spun	070	10106	China Grove	100	97	97
20/2 Type 452 Spun	072	10106	China Grove	400	421	421

bal.

## REFERENCES

The following publications are referred to either directly or indirectly for the purposes of completing the contract and writing of this report.

1. Yarns and Fabrics of Nomex

Du Pont Bulletin N-245, March 1971

2. Coated Fabrics of Dacron Polyester and Du Pont Nylon

Du Pont Bulletin X-197, June 1965

3. Development of a Fire Resistant and Rain-Protective Fabric

U. S. Army Natick Labs, December 1968

4. CCC-T-191b Textile Test Methods, December 1968

5. Military Specifications

MIL-C-4487

MIL-C-7219

MIL-C-557

MIL-C-8135

MIL-T-8363

MIL-W-17337

MIL-C-4292