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U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

REPORT NO. 660

TED PROJECT NO. NPG AR 8208

3rd Partial Report

UNBONDED NYLON FRAGMENT ARMOR FABRIC
BALLISTIC SURVEILLANCE TEST OF

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FINAL Report

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DAHLGREN, VIRGINIA

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~~Partial~~ Partial Report. NO. 13

on

TED Project No. NPG-AR-8208

9 Final Report.,

on

10 Unbonded Nylon Fragment Armor Fabric;

Ballistic Surveillance Test of .

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NAVAL PROVING GROUND C. ARMOR FRAGMENT RESISTANT SET
FIRING RECORD

SHEET NO.
ENCL. ()
SL3-1(5-)

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Manufacturer :
Type of Panels: *1/2" (NPD 20-1/1) Unbonded*
No. Submitted : 6
Date of Mfg. :
Contract : *EXPERIMENTAL*
Chemical Composition
Cloth : *Navy Blue Cotton*
Resin :
Resin Content: *—*

Physical Properties
Size of Sample: *23" x 24"*
Av. Thickness :
Av. Wt. #/sq.ft: *1.30*
Density :
Mod. of Elast.:
Flex. Strength:

Method of Processing
No. of Plies : *15*
Layup of Plies: *STRAIGHT*

Molding Cycle : *NONE*

Proj : *20MM HEAT 1/2" Frag*
Gun : *850003*
Range : *1*
Obl. : *0*
RC : *35*
Av.C (3 poorest panels): *32*
Result

Specs : *05-3563*
Group : *A*
Date : *1 Sept 1950*

762

AV. ALL-29

Panel	Unit Wt	Bullet	Charge	Str.Vel.	Condition of Plate	Trigger Plate	
						Dispersion	Av. Ga.
1	1.30	20MM	425	2709	25 Holes	7 1/2" Hole 5" High 2" Right	0.122
2	1.30	20MM	425	2717	27 Holes	6 1/2" Hole 2" High 2" Left	0.122
3	1.30	20MM	425	2727	34 Holes	8 1/2" Hole 6" High 2" Left	0.124
4	1.30	20MM	425	2722	26 Holes	7 1/2" Hole 3" High	0.124
5	1.30	20MM	424	2717	30 Holes	7 1/2" Hole 4" High 1 1/2" Left	0.123
6	1.30	20MM	424	2696	32 Holes	8" Hole 1" Left	0.122

Note: Ballistic Test Performed: *ambient Temperature 86°F*

PAGE 1

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NAVAL PROVING GROUND

ARMOR FRAGMENT RESISTANT SHEET FIRING RECORD R-E-S-T-R-I-C-T-E-D

 SHEET NO.
ENCL. ()
S13-1(5-)

Manufacturer :
 Type of Panels: *NYLON (NFD-202/1) UNBONDED*
 No. Submitted : *6*
 Date of Mfg. :
 Contract : *EXPERIMENTAL*
 Chemical Composition
 Cloth : *Nylon Basket Weave*
 Resin :
 Resin Content: *---*

Physical Properties
 Size of Sample: *23" X 24"*
 Av. Thickness :
 Av. Wt. #/sq.ft: *1.82*
 Density :
 Mod. of Elast.:
 Flex. Strength:

Method of Processing.

No. of Plies : *21*
 Layup of Plies: *straight*

Molding Cycle : *None*

Proj : *20MM HE MK3 MK26-1 Fuze* Specs : *OS-3563*
 Gun : *850003* Group : *B*
 Range : *1* Date : *1 Sept. 1950*
 Obl. : *0°*
 RC : *22*
 Av.C (3 poorest panels): *1.7* AV. ALL - *18.7*
 Result

Panel	Unit Wt	Bullet	Charge	Str. Vel.	Condition of Plate	Trigger Plate	
						Dispersion	Av. Ga.
<i>1</i>	<i>1.82</i>	<i>20MM</i>	<i>423</i>	<i>2725</i>	<i>21 Holes</i>	<i>7" Hole 3" left</i>	<i>0.121</i>
<i>2</i>	<i>1.82</i>	<i>"</i>	<i>423</i>	<i>2709</i>	<i>22 Holes</i>	<i>8" Hole 1" left</i>	<i>0.123</i>
<i>3</i>	<i>1.82</i>	<i>"</i>	<i>423</i>	<i>2714</i>	<i>17 Holes</i>	<i>8" Hole 1" left</i>	<i>0.123</i>
<i>4</i>	<i>1.82</i>	<i>"</i>	<i>423</i>	<i>2699</i>	<i>16 Holes</i>	<i>7 1/2" Hole 1" left</i>	<i>0.122</i>
<i>5</i>	<i>1.82</i>	<i>"</i>	<i>423</i>	<i>2720</i>	<i>22 Holes</i>	<i>8" Hole 1" left</i>	<i>0.121</i>
<i>6</i>	<i>1.82</i>	<i>"</i>	<i>423</i>	<i>2699</i>	<i>14 Holes</i>	<i>8" Hole 1" left</i>	<i>0.121</i>

Note: Ballistic Test Performed: *Ambient Temperature 86°F*

NAVAL PROVING GROUND

ARMOR FRAGMENT RESISTANT SHEET
FIRING RECORD
R-E-S-T-R-I-C-T-E-D

SHEET NO.
ENCL. ()
S13-1(5-)

Manufacturer :
Type of Panels: *NYLON (NFD-202/1) UNBONDED*
No. Submitted : *6*
Date of Mfg. :
Contract : *EXPERIMENTAL*
Chemical Composition
Cloth : *NYLON Double Weave*
Resin :
Resin Content: *---*

Physical Properties
Size of Sample: *23" x 24"*
Av. Thickness :
Av. Wt. #/sq.ft: *2.78*
Density :
Mod. of Elast.:
Flex. Strength:

Method of Processing
No. of Plies : *32*
Layup of Plies: *Straight*
Molding Cycle : *None*

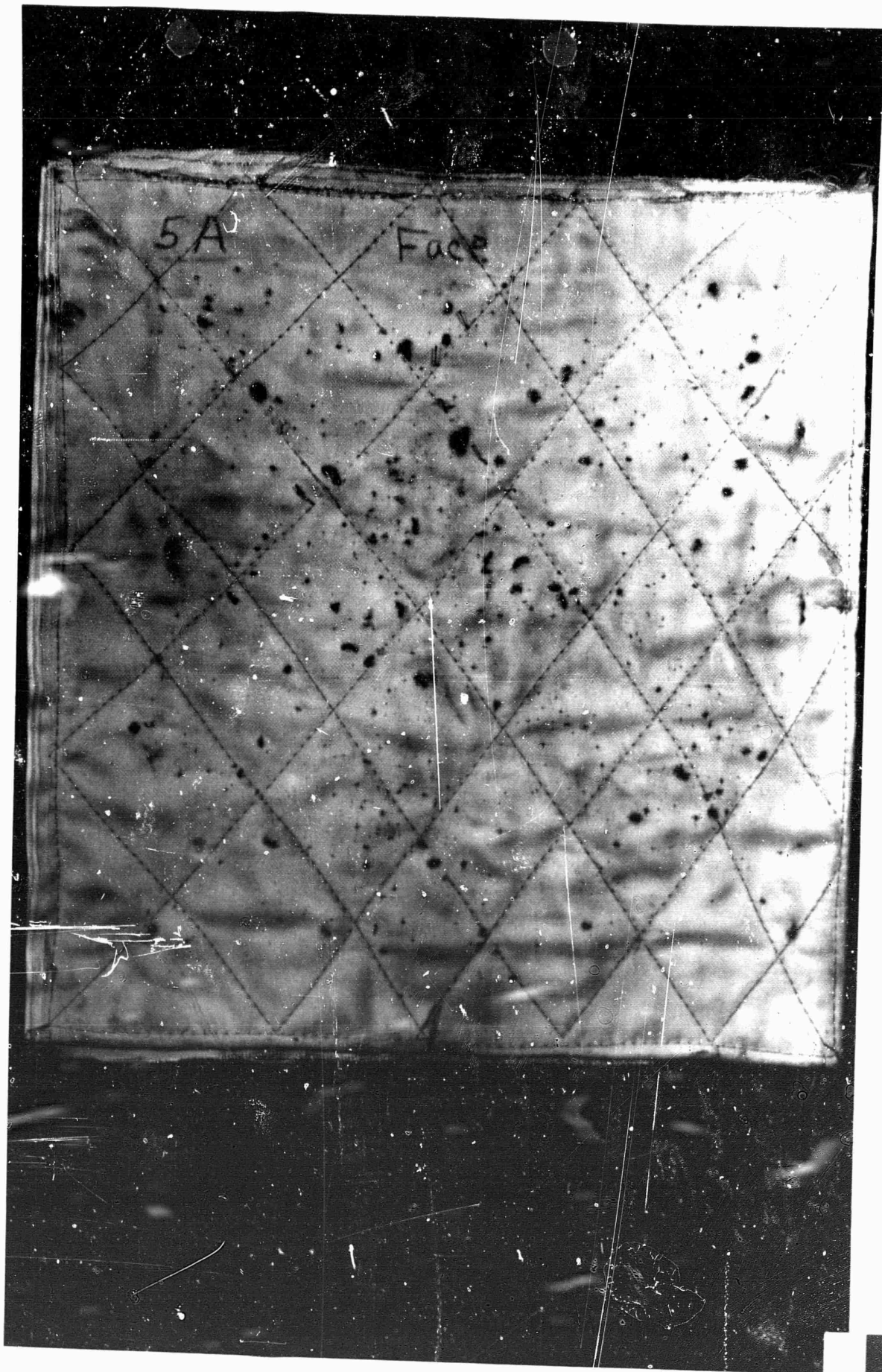
Proj : *20MM HE MK.3 MK 26-1 Fuz* Specs : *OS-3563*
Gun : *850003* Group : *C*
Range : *1* Date : *1 Sept. 1950*
Obl. : *0°*
RC : *8*
Av.C (3 poorest panels): *9.7* *AV. ALL - 8.3*
Result

							Trigger Plate
Panel	Unit Wt	Bullet	Charge	Str.Vel.	Condition of Plate	Dispersion	Av. Ga.
<i>1</i>	<i>2.78</i>	<i>20MM</i>	<i>423</i>	<i>2707</i>	<i>8 Holes</i>	<i>7" Hole 1 1/2 ft</i>	<i>0.121</i>
<i>2</i>	<i>2.78</i>	<i>"</i>	<i>423</i>	<i>2707</i>	<i>7 Holes</i>	<i>7 1/2 Hole 2 1/4 ft</i>	<i>0.123</i>
<i>3</i>	<i>3.78</i>	<i>"</i>	<i>423</i>	<i>2714</i>	<i>10 Holes</i>	<i>8 1/2 Hole 3 1/4 ft</i>	<i>0.123</i>
<i>4</i>	<i>2.78</i>	<i>"</i>	<i>423</i>	<i>2712</i>	<i>10 Holes</i>	<i>8" Hole 3 1/4 ft</i>	<i>0.123</i>
<i>5</i>	<i>2.78</i>	<i>"</i>	<i>423</i>	<i>2714</i>	<i>9 Holes</i>	<i>7 1/2 Hole 4 ft</i>	<i>0.122</i>
<i>6</i>	<i>2.78</i>	<i>"</i>	<i>423</i>	<i>2704</i>	<i>6 Holes</i>	<i>7 1/2 Hole 2 1/4 ft</i>	<i>0.123</i>

Note: Ballistic Test Performed: *Ambient temperature 86°F*

NP9 42687 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 5A, Plies - 15, Ave. wt. lbs./ft. 2-1.30, No. of Penetrations - 30. Front View.
1 Sept. 1950

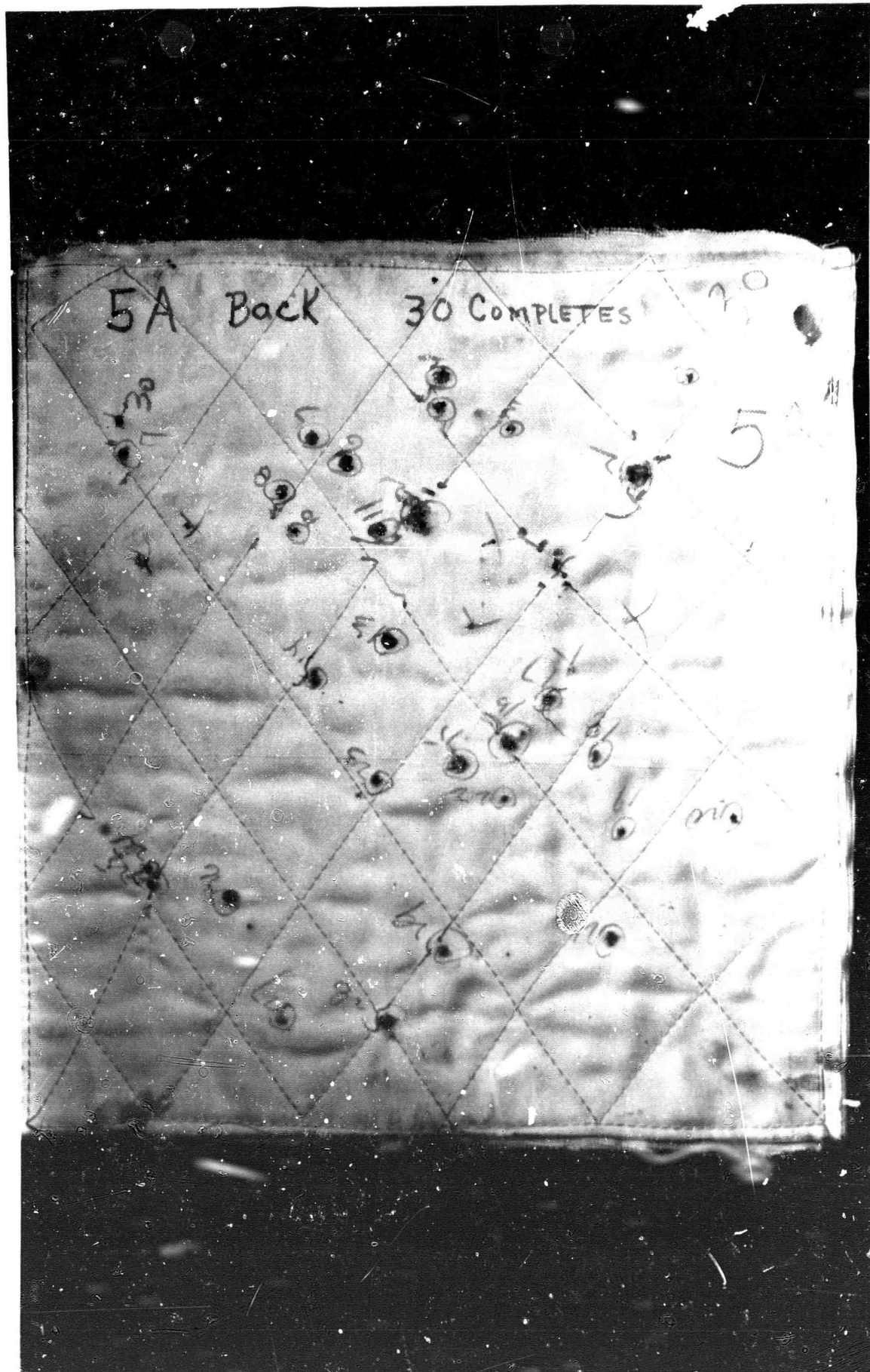
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NP9 42688 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 5A, Plies - 15, Ave. wt. lbs./ft. 2 - 1.30, No. of Penetrations - 30. Back View.

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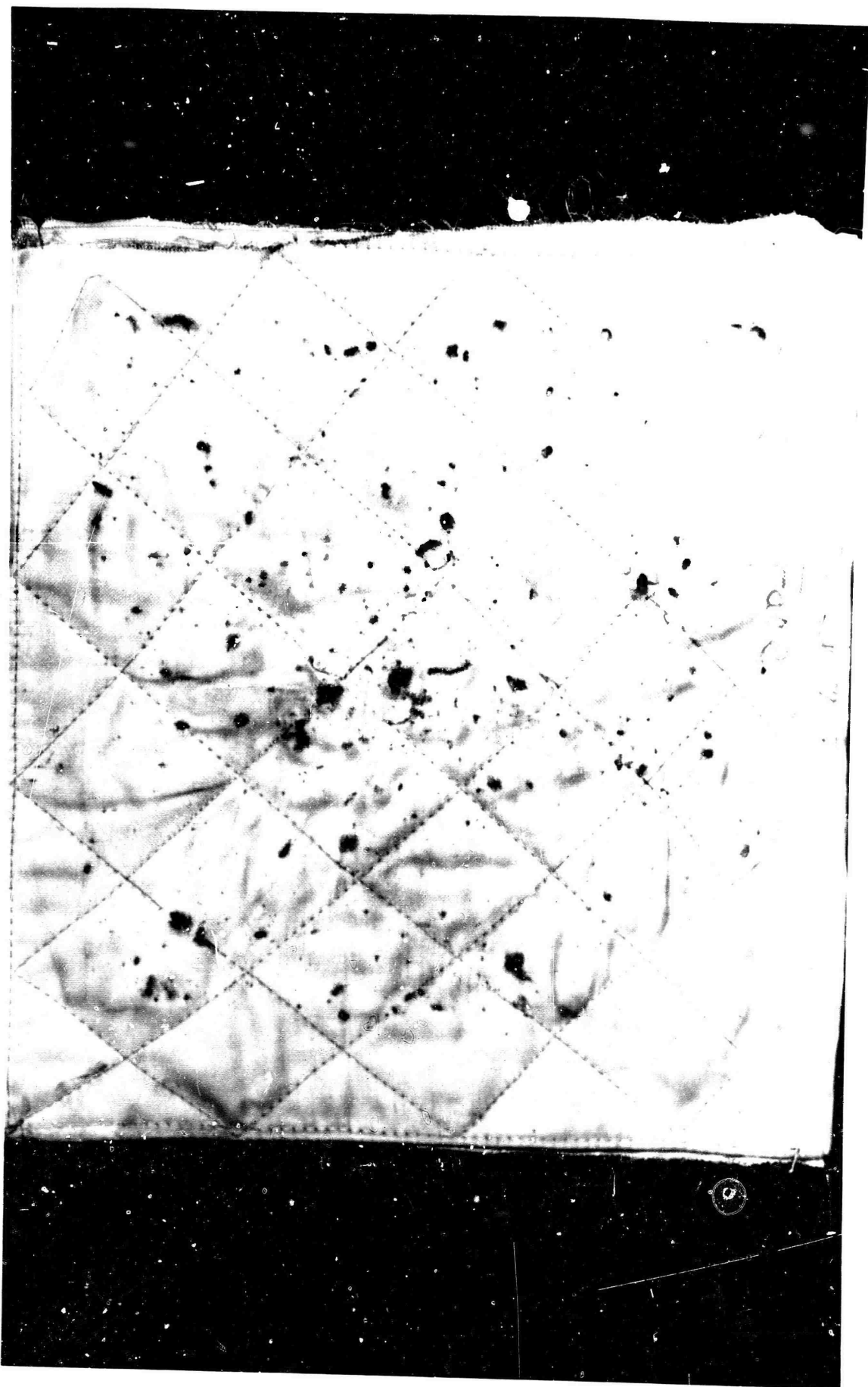
Figure 2



SP9 42689 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested
with 20mm HE Forward Fragment Spray. Panel No. - 48, Piles - 21, Ave. wt. lbs./ft. 2 -
1.82, No. of Penetrations - 16. Front View.
1 Sept. 1950

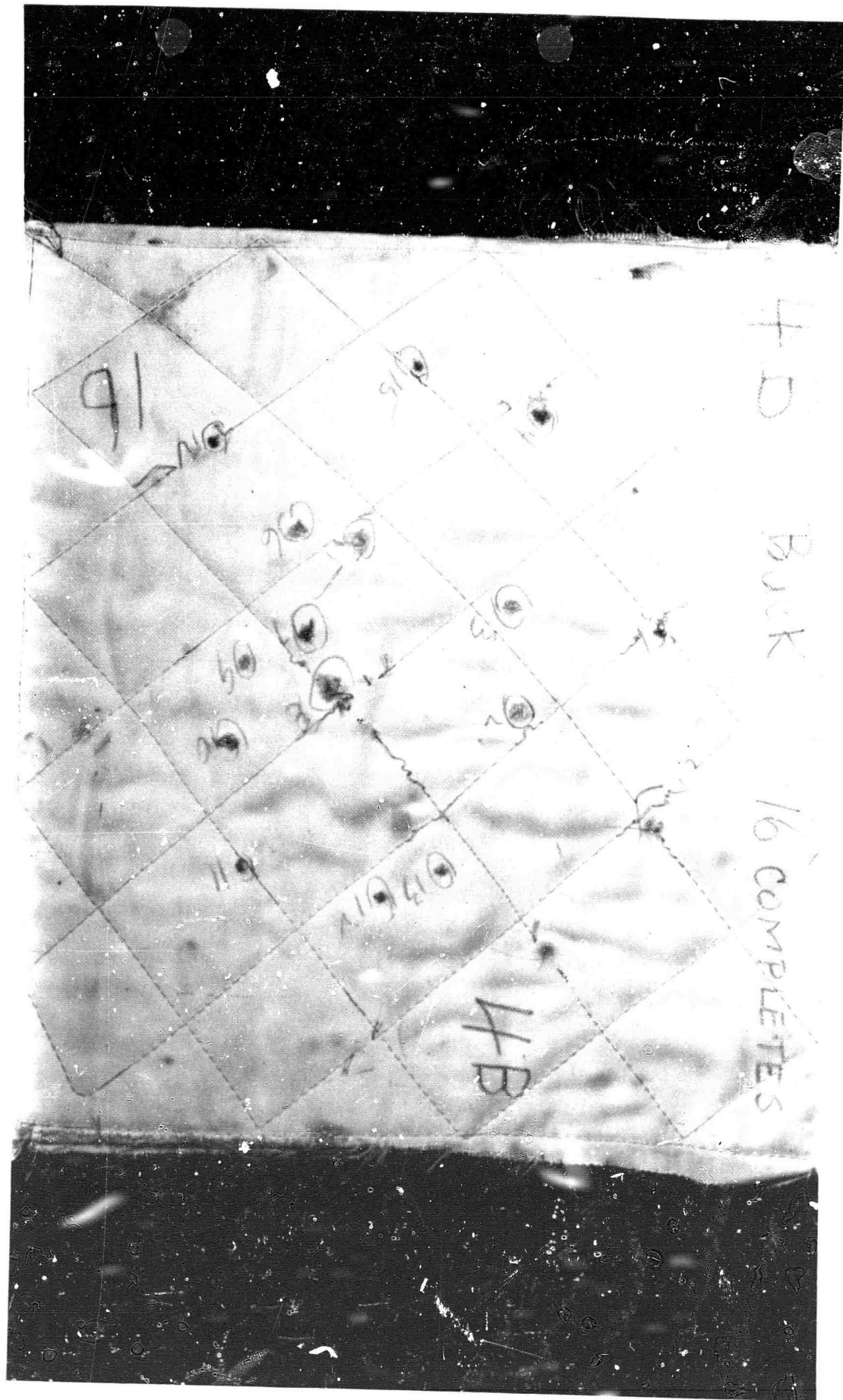
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Figure 3



NP9 42690 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 4B, Plies - 21, Ave. wt. lbs./ft. 2 - 1.82, No. of Penetrations - 16. Back View. Figure 4

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NP9 42691 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray, Panel No. - 6C, plies - 32, Ave. wt. lbs./ft. 2 - 2.78, No. of Penetrations - 6. Front View. Figure 5

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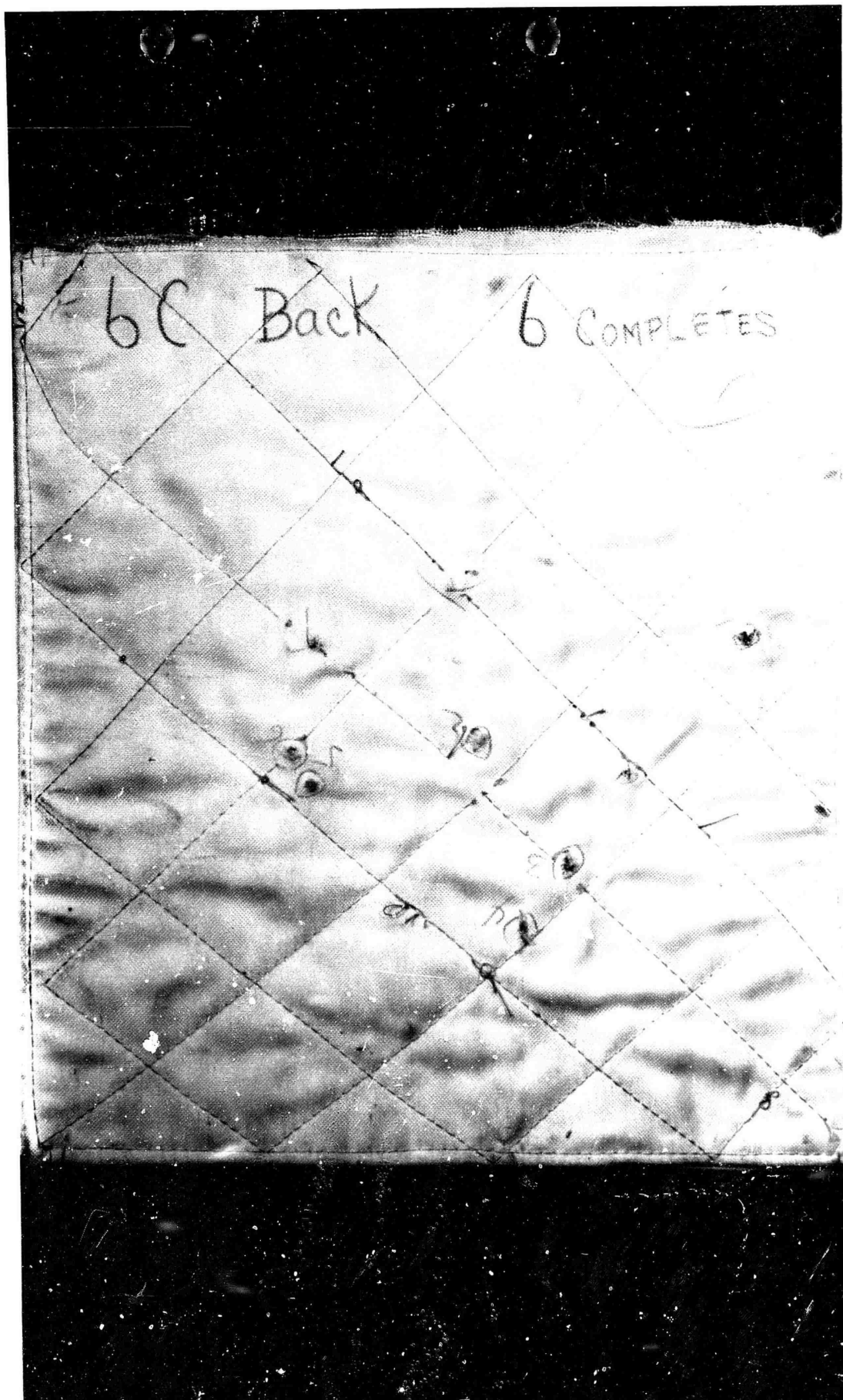


NP9 42692 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 60, Plies - 32, Ave. wt. lbs./ft. 2 - 2.78, No. of penetrations - 6. Back View.

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Figure 6

1 Sept. 1950

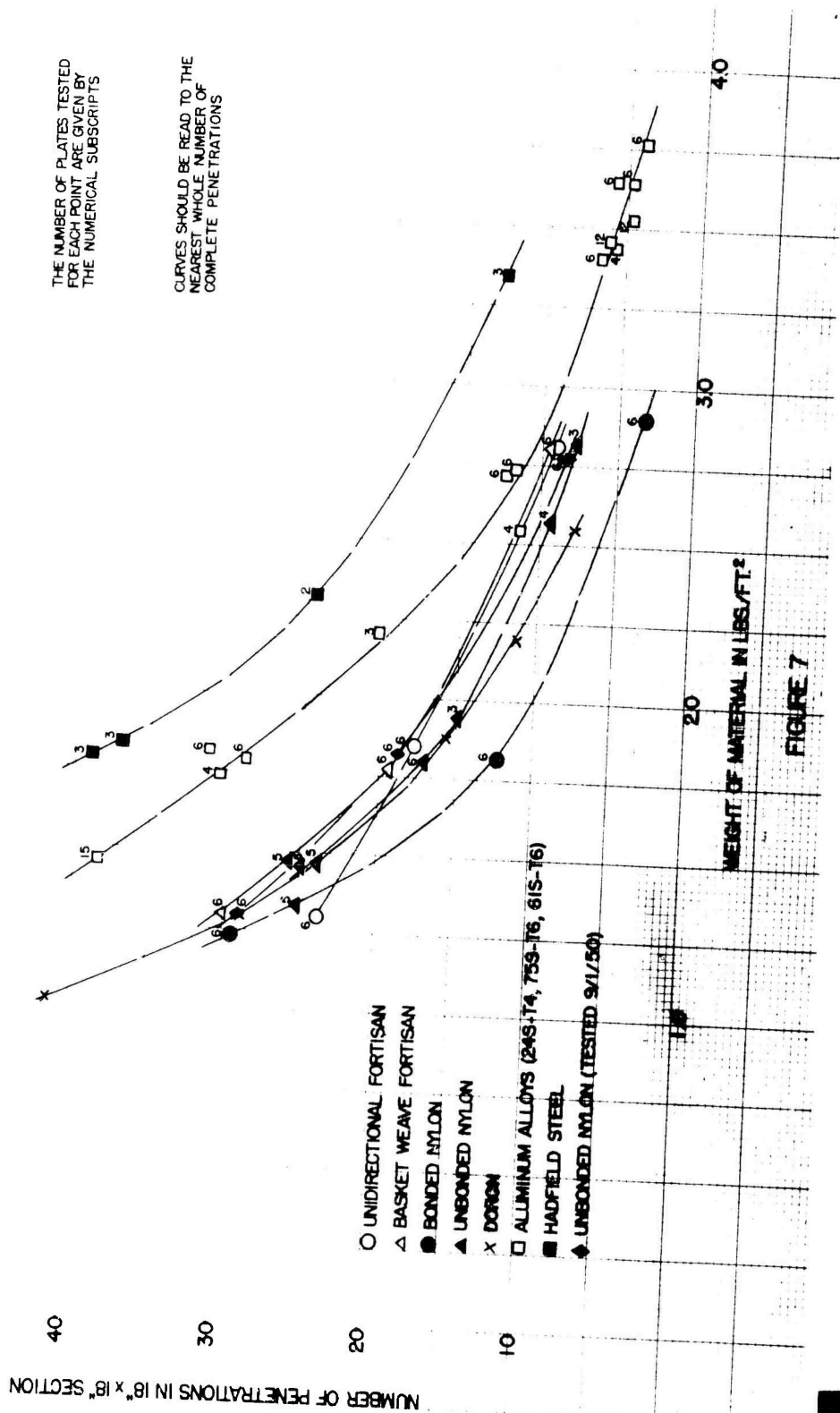


20MM HE FORWARD FRAGMENT RESISTANT SPRAY VERSUS
VARIOUS TYPES OF FRAGMENT RESISTANT ARMOR (18" x 18" SECTIONS)

RESTRICTED

MK. 3 PROJECTILES, MK. 26 MOD 1 FUZES
PROJECTILES DETONATED IN FLIGHT AT SERVICE VELOCITY (2700 F.S.)
ON 1/8" MILD STEEL NORMAL TO LINE OF FLIGHT TARGET PANEL
PARALLEL TO AND 3' BEHIND TRIGGER PLATE

50



Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

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APPENDIX D

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NPG REPORT NO. 660

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

PART A

SYNOPSIS

1. The Bureau of Aeronautics is interested in utilizing in flak jackets and curtains some Nylon fabric that has been in storage for some time. This test was conducted to determine the fragment resisting properties with the 20mm HE forward fragment spray test of basket weave Nylon which had been in storage and to compare the results with the results obtained on similar materials tested previously, namely unbonded Nylon.

2. The unbonded Nylon panels, fabricated from basket weave cloth that had been in storage for some time, as tested herein exhibited satisfactory performance against 20mm HE forward spray fragments at weights of 1.30, 1.82 and 2.78 lbs./ft.².

3. At the lighter weights of 1.30 and 1.82 lbs./ft.², the performance of the subject Nylon panels was slightly inferior to that of unbonded Nylon tested previously. However, at a weight of 2.78 lbs./ft.² the performance was equivalent to that of unbonded Nylon tested previously.

4. The results obtained in this test indicate that the quality of the subject Nylon fabric is suitable for fabrication into flak jackets and curtains.

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Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

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NPG REPORT NO. 660

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

PART B

INTRODUCTION

1. AUTHORITY:

The subject test, authorized by reference (a), was conducted under Bureau of Aeronautics TED Project NPG AR 8208 as established by reference (b).

2. REFERENCES:

- a. BUAER ltr (Aer-AE-44) 67076 of 25 August 1950 to NAVPROV via BUORD. End 1 by BUORD Re8a-MHS:ejb F41-1(HG) of 12 September 1950.
- b. BUAER ltr (Aer-AR-82) 81624 of 3 August 1949 to NAVPROV via BUORD. End 1 by BUORD S13-1(4)Re3 of 10 August 1949 to NAVPROV.
- c. BUORD Spec O.S. 3563.
- d. NAVPROV ltr S13-1(5)(BXO 77576) of 10 November 1944 to BUORD.
- e. NAVPROV ltr S13-1(5)(BXO 74074) of 16 September 1944 to BUORD.
- f. NAVPROV ltr S13-1(5)(EP0 84791) of 29 March 1945 to BUORD.
- g. NAVPROV ltr S13-1(5)(EP0 91528) of 12 July 1945 to BUORD.
- h. NAVPROV ltr S13-1(5)(EP0 94337) of 15 April 1946 to BUORD.
- i. NAVPROV ltr S13-1(5)(EP0 89990) of 7 June 1945 to BUORD.
- j. NPG Report No. 26 of 13 May 1948.
- k. NPG Report No. 392 of 5 October 1949.

3. BACKGROUND:

Fragment resistant armor materials including unbonded Nylon of various types have been tested previously at the Naval Proving Ground. A quantity of Nylon basket weave cloth has been stored for some time at the Aviation Supply Office, Philadelphia. The Bureau of Aeronautics is presently interested in utilizing this material for flak jackets and curtains. Thus, the Naval Proving Ground was requested to fabricate various weight panels from this material and determine the fragment resisting properties thereof.

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Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

4. OBJECT OF TEST:

This test was conducted to determine the fragment resisting properties with the 20mm HE forward fragment spray test of basket weave Nylon which had been in storage and to compare the results with the results obtained on similar materials tested previously.

5. PERIOD OF TEST:

a. Date of Authorizing Letter	25 August 1950
b. Date Material Received	11 August 1950
c. Date Commenced Test	1 September 1950
d. Date Test Completed	1 September 1950

PART C

DETAILS OF TEST

6. DESCRIPTION OF ITEM UNDER TEST:

Approximately 800 feet of basket weave Nylon cloth reported to be NFD-202/1 by the Bureau of Aeronautics was received at the Naval Proving Ground on 11 August 1950. This material was found to weigh approximately .087 lbs./ft.². Test panels of 1.30, 1.82 and 2.78 lbs./ft.² were processed from this material. The panels processed were as follows:

<u>No. of Panels</u>	<u>No. of Plies</u>	<u>Size</u>	<u>Av. Weight lbs./ft.²</u>
6	15	23" x 24"	1.30
6	21	23" x 24"	1.82
6	32	23" x 24"	2.78

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Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

7. DESCRIPTION OF TEST EQUIPMENT:

a. Ammunition and Gun.

20mm HE projectiles Mk. 3 with fuzes Mk. 26 Mod. 1.
Gun No. 850003.

b. Triggering Plates.

Cold rolled strip steel (2' x 2' x 0.125 ± .005) in dead
soft temper at Rockwell B hardness 45 ± 7.

c. A 150' range with target mounting jig and velocity
measuring equipment.

8. PROCEDURE:

The test panels were masked off to leave exposed sections
18" x 18". A total of six (6) 18" x 18" sections of each weight
were given the 20mm HE forward fragment spray test in accordance
with the procedure outlined in paragraph F-7 of reference (c).
This procedure consists of testing each 18" x 18" exposed section
with fragments from one 20mm HE Mk. 3 projectile ~~fuzed~~ with a
Mk. 26 Mod. 1 fuze detonated in flight at service velocity on a
0.125 mild steel plate 3 feet forward of the section. The striking
velocity of the projectile on the triggering plate was held to
2700 ± 50 ft./sec.. The triggering plate and test section were
both placed normal to the line of fire and positioned so that the
projected line of fire passed through the center of both.

9. RESULTS AND DISCUSSION:

a. The results are given in detail in Appendix (A) and are
summarized below:

<u>No. of Plies</u>	<u>Average Weight lbs./ft.²</u>	<u>Penetrations in 18" x 18" Sections (Av. of 6)</u>	<u>Penetrations Average of 3 Poorest of 6 Tested</u>	<u>Allowed Ref. (c) 3 Poorest</u>	<u>Remarks</u>
15	1.30	29	32	35	Passed
21	1.82	18.7	21.7	22	Passed
32	2.78	8.3	9.7	8	Failed

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NPG REPORT NO. 660

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

b. Photographs of representative panels after ballistic test are contained in Appendix (B).

c. The test panels assembled from the Nylon basket weave cloth passed the ballistic requirements of reference (c) at normal temperature by (+3) penetrations at 1.30 lbs./ft.² and by (+0) penetrations at 1.82 lbs./ft.², but failed by (-2) penetrations at 2.78 lbs./ft.².

d. In Appendix (C) the number of complete penetrations of 18" x 18" sections of various fragment resistant armors are plotted against the weight of each material in lbs./ft.². The complete penetrations versus weight curves as drawn in Appendix (C) indicates the efficiency of the various materials in stopping 20mm HE forward spray fragments. Thus, from these curves a comparison of the performance of the Nylon cloth as tested herein and similar type Nylon cloth tested previously can be obtained. These curves are based on data obtained from sources as listed below:

<u>Material</u>	<u>Source of Data</u>
Unbonded Nylon (NFD-202/1)	As tested herein
Fortisan Basket Weave	Reference (k)
Fortisan Unidirectional	Reference (k)
Bonded Nylon	Reference (d)
Unbonded Nylon	Reference (e), (f), (g), (h)
Doron	Acceptance and experimental ballistic tests of over 2000 panels performed in 1944 and 1945
Aluminum Alloy	References (e), (i), (j)
Hadfield Steel	Reference (d)

e. Appendix (C) shows that at weights of 1.30 and 1.82 lbs./ft.² the subject unbonded basket weave Nylon panels had slightly more fragment penetrations than did unbonded Nylon panels tested previously. At a weight of 2.78 lb./ft.² the number of penetrations were approximately the same for the subject unbonded Nylon and unbonded Nylon tested previously.

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Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

f. The results of the subject test were reported to Mr. R. Temple (Aer-AE-44) by telephone on 4 September 1950 in order to facilitate action as regards to fabrication of flak jackets and curtains from the subject Nylon fabric.

PART D

CONCLUSIONS

10. a. The unbonded Nylon panels, fabricated from basket weave cloth that had been in storage for some time, as tested herein exhibited satisfactory performance against 20mm HE forward spray fragments at weights of 1.30, 1.82 and 2.78 lbs./ft.².

b. At the lighter weights of 1.30 and 1.82 lbs./ft.², the performance of the subject Nylon panels was slightly inferior to that of unbonded Nylon tested previously. However, at a weight of 2.78 lbs./ft.² the performance was equivalent to that of unbonded Nylon tested previously.

c. The results obtained in this test indicate that the quality of the subject Nylon fabric is suitable for fabrication into flak jackets and curtains.

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Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

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Lieutenant Commander, USN
Terminal Ballistics Test
Officer

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Terminal Ballistics Officer

CONCUR: *C. T. Mauro*

C. T. MAURO
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Rear Admiral, USN
Commander, Naval Proving Ground

C. H. Anderson
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