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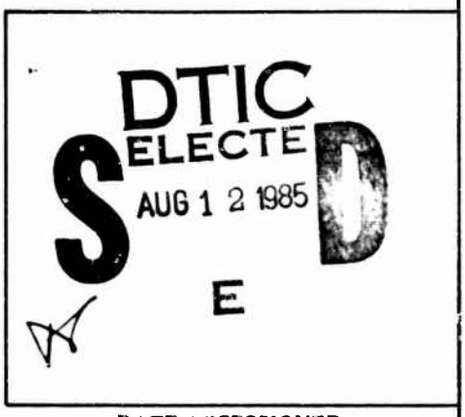

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/755

Resistance of Various Fabrics to Perforation

by Fragment-Simulating Projectiles

Note: Should have been restricted originally

BY

J. F. Sullivan
Asst. Engineer

Recoded Uncl by AuthH of C. O. Watertown Arsenal in compliance w/Par 25, AR 380-5, dtd 6 June 1952

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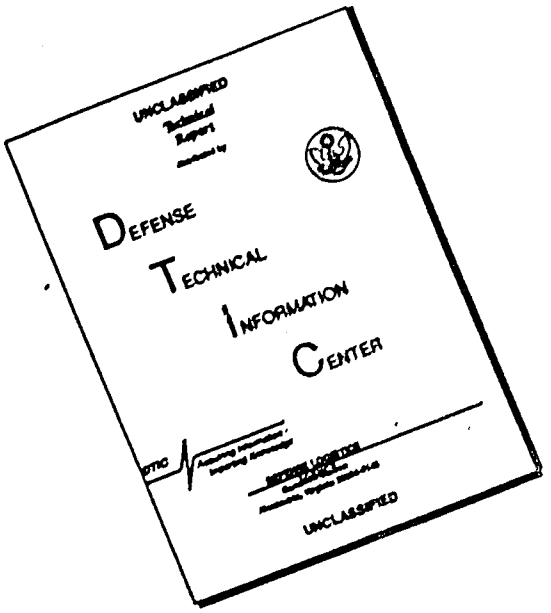

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/755

Partial Report on Problem B-6.2

15 June 1945

Resistance of Various Fabrics to Perforation by Fragment-Simulating Projectiles

1. In response to requests of the Office, Chief of Ordnance,[1-14], tests have been conducted over a period of several months at this laboratory on various fabrics which have been suggested as possible components of body armor assemblies. The results of these tests have been reported, as they have been completed, in Watertown Arsenal Reports[15-24], but in this report an attempt will be made to evaluate their relative resistance to perforation by fragment-simulating projectiles.

2. Since a disappointing lack of correlation has been observed between results of ballistic limit tests made with fragment-simulating projectiles developed here[25-27] and the results of actual fragmentation tests which probably most nearly simulate actual service conditions, no attempt will be made to predict the relative resistance of these materials to perforation by fragments actually encountered in service. However, conclusions will be drawn as to their comparative resistance to perforation by the test projectiles used at this laboratory.

3. The results of the various tests conducted are recited in Tables I through X. In Tables XI and XII the various samples are listed in order of figures of merit for resistance to perforation by cal. .45 ball projectiles and cal. .22 fragment-simulating projectiles, G-2, respectively. These figures of merit are based on the relation between the resistance of a sample to perforation by a given projectile and the resistance of an equivalent weight of Hadfield manganese steel. Since this latter characteristic is reliably known only over the thickness range .040" to .050", figures of merit have been assigned only to samples whose weight-per-unit-area is equivalent to that of Hadfield steel of that thickness range. Tables XIII and XIV list average figures of merit for the various types of fabrics and afford some basis for relatively evaluating them.

4. Thus under normal impact of cal. .45 (steel-jacketed) ball projectiles, the sized samples of nylon duck, the best type of fiberglas (ECC-136) and the sample of silk-webbing afforded resistance equivalently superior to other materials and under impact of cal. .22 fragment-simulating projectiles, G-2,

samples of nylon parachute cloth afforded best resistance, followed by sized nylon duck and silk webbing which were equivalent in resistance. It would, therefore, appear that, as regards overall resistance to both types of attack, sized nylon duck or silk webbing should afford the best protection.

5. Since the cal. .45 ball projectile and the cal. .22 fragment-simulator represent widely divergent characters of attack it might be tentatively suggested that either of these two materials could be expected to afford better resistance against actual fragments than other fabrics, since actual fragments of high explosive shell attack in a variety of sizes, shapes, velocities and manners of presentation. The actual resistance to actual fragment attack of sized nylon duck, only, is well established, however, and no evidence of correlation between results of actual fragmentation tests of fabrics and ballistic limit tests on fabrics is available. Nevertheless, since the actual resistance of sized nylon duck to actual fragments is very high, there may be lying dormant an actual correlation with respect to tests of fabrics.

6. It is interesting to note that a correlation between resistance to each type of projectiles and weaving characteristics was found in tests of fiberglas.

7. In those instances where the resistance of several plies of a particular fabric was compared with the resistance of the same fabric in the form of webbing, the webbing appeared to be considerably inferior. This immediately raises the fascinating question whether the resistance of plied silk would show a similar superiority to silk webbing which was nearly the best material tested.

8. The resistance of cotton duck to perforation by these test projectiles was spectacularly low. If its comparative resistance to perforation by actual fragments is equivalently low, some thought should be given to the substitution of a more protective fabric in the construction of tents, sleeping bags and other shelters.

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22. Report No. WAL 710/653. "Resistance of Various Samples of Fiberglas to Perforation by Fragment-Simulating Projectiles." J. F. Sullivan, 10 June 1944.

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27. Report No. WAL 762/314. "Comparison of C-2 Projectiles of Various Manufacture." J. F. Sullivan, 23 May 1945.

TABLE I

(Reference Report No. WAL 710/616)

Summary of Ballistic Tests Conducted at Watertown Arsenal on Various Multi-Layered Assemblies of 17-1/2 Ounce Nylon Duck

Sample	Equivalent Steel Gauge	Ballistic Limits C-1-A[1]	C-1-S[2]	C-2[3]	.45[4]
Stretched tautly across a wooden ballistic frame-back unsupported:					
6 Plies Nylon Duck	.022"	---	790	---	---
7 Plies Nylon Duck	.026"	515	844	1095	---
8 Plies Nylon Duck	.029"	498	938	1105	---
9 Plies Nylon Duck	.033"	550	946	---	500
10 Plies Nylon Duck	.037"	545	981	1215	675
11 Plies Nylon Duck	.040"	567	1058	1310	704
12 Plies Nylon Duck	.044"	566	1105	1560	750
150 Plies Nylon Parachute Cloth	.045"	---	---	1467	698
11 Plies #8 Cotton Duck	.047"	---	---	---	395
17 Plies Fiber Glass ECC-11-162 Plus 3 Plies Nylon Duck	.045"	---	---	1208	766
Hadfield Manganese Steel (Average)	.041"	---	1050	1660	940
Strapped on sawdust-filled canvas dummy:					
6 Plies Nylon Duck	.022"	---	865	---	---
7 Plies Nylon Duck	.026"	---	948	1064	---
8 Plies Nylon Duck	.029"	---	972	1081	---
9 Plies Nylon Duck	.033"	---	1020	---	---
10 Plies Nylon Duck	.037"	---	1065	1207	---
11 Plies Nylon Duck	.040"	---	1090	1560	---
12 Plies Nylon Duck	.044"	---	1102	---	---
11 Plies #8 Cotton Duck	.047"	---	---	883	---
25 Plies Fiber Glass ECC-11-162	.045"	---	---	1189	---

1. Cal. .30 (150 grains)
2. Cal. .30 (34 grains)
3. Cal. .22 (17 grains)
4. Standard Cal. .45 ball ammunitions.

TABLE II
(Reference Report No. WAL 710/596)

Comparison of Ballistic Limits of Various Numbers of Layers of 17-1/2 Ounce Nylon Duck, as Rigidly Mounted, and as Loosely Mounted with Those of Hadfield Manganese Steel of Equivalent Weight

Number of Layers	Equivalent Steel Thickness	Ballistic Limit with 34-Grain Fragment-Simulating Projectile G-1-S		
		Rigid	Loose	Steel of Equivalent Weight
6	.022	790	865	----
7		844	948	----
8		938	972	----
9	.033	946	1020	----
10		981	1063	----
11		1058	1090	880
12	.044	1105	1102	1020

TABLE III
(Reference Report No. WAL 710/540)

Comparison of Resistance Characteristics of Unsized 19-Ounce Nylon Duck with Those of Sized 17-1/2-Ounce Nylon Duck

Material	Plies	Equivalent Steel Gauge	Ballistic Limit F/S	
			Cal. .45[1]	G-2[2]
17-1/2-Ounce, Sized	9	.033"	500	----
19-Ounce, Unsized	11	.036"	627	1260
17-1/2-Ounce, Sized	10	.037"	675	1215
19-Ounce, Unsized	12	.039"	629	1283
17-1/2-Ounce, Sized	11	.040"	704	1310
19-Ounce, Unsized	13	.043"	685	1309
17-1/2-Ounce, Sized	12	.044"	750	1360
19-Ounce, Unsized	14	.046"	688	1350

1. Cal. .45 steel-jacketed ball projectile - 230 grains.

2. Cal. .22 fragment-simulating projectile - 17 grains.

TABLE IVa
(Reference Report No. WAL 710/680)

Summary of Penetration Tests Conducted at Watertown Arsenal on Samples of Nylon Parachute Cloth

Sample	Equivalent Steel Gauge	Ballistic Limit (F/S) G-2[1]	Ballistic Limit (F/S) Cal. .45[2]
NFD-168/3	.044"	1370	676
NFD-170	.044"	1435	656
NFD-172	.044"	1435	712
For Comparison:			
17-1/2 oz. Nylon Duck	.044"	1360	750

1. Cal. .22 fragment-simulating projectile - 17 grains.

2. Cal. .45 (steel-jacketed) ball projectile - 230 grains.

TABLE IVb
(Reference Report No. WAL 710/660)

Data Concerning Three Samples of Nylon Parachute Cloth
as Reported by E. I. DuPont de Nemours and Company

	DuPont Style Number		
	NFD-170	NFD-168/3	NFD-172
Yarn Type	Bright High Tenacity	Bright High Tenacity	Bright High Tenacity
Yarn Count: Warp	70-23-5	70-23-7	105-34-5
Filling	70-23-5	70-23-7	105-34-5
Weave	Cargo	2 x 1 Twill Rip-Stop	Taffeta
Construction (loom count)	80 x 84	84 x 92	60 x 64
Reed	4012	4212	3012
Reed Width	40"	40.9"	40"
Pickwheel	84	90	64
Finisher	Huguet	Huguet	Huguet
Finished Construction	90 x 88	96 x 98	68 x 67
Finished Width	35-1/8"	36"	34-3/4"
Porosity	115	128	81
Thickness	0.0055"	0.0056"	0.0062"
Weight (oz./sq.yd.)	1.83	2.00	2.04
Tensile Strength (1" strip)	94x86 lbs.	99x98 lbs.	111x104 lbs.
Tear (Tongue)	6.8x7.2 lbs.	12.7x12.1 lbs.	9.6x9.4 lbs.
Tear (Trapezoid)	14.3x16.7 lbs.	-----	29.5x27.0 lbs.
Elongation	26 x 38%	25 x 32%	23 x 45%

TABLE V
(Reference Report No. WAL 710/614)

Summary of Ballistic Tests Conducted at Watertown Arsenal on Two Types of Nylon Bolting Designated 63-2851 and 63-2851A

Sample	Equivalent Steel Gauge	G-1-A[1]	G-1-S[2]	G-2[3]	.45[4]
Stretched tautly across a wooden ballistic frame-back unsupported:					
63-2851	.040"	484	840	973	517
63-2851A	.041"	496	791	1053	537
11 Plies Nylon Duck (17-1/2 oz.)	.040"	567	1058	1310	704
Hadfield Steel (Average)	.040"	—	900	1600	900
Strapped to sawdust-filled canvas dummy:					
63-2851	.040"	500	896	1075	—
63-2851	.041"	—	806	1085	—
11 Plies Nylon Duck (17-1/2 oz.)	.040"	—	1090	1360	—

1. Cal. .30 (150 grains)
2. Cal. .30 (54 grains)
3. Cal. .22 (17 grains)
4. Standard Cal. .45 ball ammunition

TABLE VI
(Reference Report No. WAL 710/610)

Summary of Ballistic Tests Conducted at Watertown Arsenal on Various Assemblies of Fibre Glass ECC-11-162

Test Sample	Quilting Interval	Equivalent Steel Gauge	Ballistic Limit G.2 (Cal. .22, 17 Grains)	Ballistic Limit Standard Cal. .45 Ball
Tautly stretched on rigid wooden frame - back unsupported:				
21 Plies Fiber Glass Plus 1 Ply Nylon Duck	8"	.045"	1150	711
"	4"	.045"	1148	729
"	1"	.045"	1175	738
"	1/2"	.045"	1138	697
25 Plies Fiber Glass	2"	.043"	----	710
17 Plies Fiber Glass Plus 3 Plies Nylon Duck	2"	.045"	1208	760
25 Plies Fiber Glass Plus 1 Ply Nylon Duck	2"	.049"	1290	—
21 Plies Fiber Glass Plus 3 Plies Nylon Duck	2"	.053"	1335	856
12 Plies Nylon Duck	11"	.044"	1360	750
Hadfield Manganese Steel (Average)	--	.044"	1660	940
Strapped to sawdust-filled canvas dummy:				
25 Plies Fiber Glass	2"	.045"	1189	—
25 Plies Fiber Glass Plus 1 Ply Nylon Duck	2"	.049"	1238	—
11 Plies Nylon Duck	11"	.020"	1360	—

TABLE VIIa
(Reference Report No. WAL 710/653)

Summary of Ballistic Tests Conducted at Watertown Arsenal on Various Samples of "Fiberglas" submitted by Owens-Corning Fiberglas Corporation

Sample	No. of Plies	Equivalent Steel Gauge	Ballistic Limit (F/S) Cal. .45[1]	Ballistic Limit (F/S) G-2[2]
ECC-112	107	.044"	698	1056
ECC-113	96	.044"	525	1101
ECC-115	94	.044"	588	1050
ECC-116	75	.044"	696	1062
ECC-117	79	.044"	671	974
ECC-127	58	.044"	647	1082
ECC-128	45	.044"	595	1090
ECC-138	32	.044"	694	1154
ECC-138a	32	.044"	738	1108
ECC-161	18	.044"	732	1188
ECC-162	19	.044"	618	956
X-1549	14	.044"	669	1022
X-1581	39	.044"	549	988
For Comparison:				
17-1/2 Ounce Nylon Duck	12	.044"	750	1560
Hadfield Manganese Steel (Average)		.044"	940	1660

1. Cal. .45 (steel-jacketed) ball projectiles - 230 grains.
2. Cal. .22 fragment-simulating projectile - 17 grains.

TABLE VIIb
(Reference Report No. WAL 710/655)

Physical Properties of Fiberglas Samples as Reported by Owens-Corning Fiberglas Corporation

Fabric #	Weight ozs. Sq.Yd.	Thickness Inches MM	Ends Per Inch	Picks per Inch	Weave	Warp Yarn	Fill Yarn	Break Str. Lbs./" Warp	Break Str. Lbs./" Fill
ECC-112	2.5	.005	40	39	Plain	450-1/2-5 TPI	450-1/2-5 TPI	110	105
ECC-115	2.5	.004	48	48	"	225-1/0-1½ TPI	225-1/0-1½ TPI	115	120
ECC-116	3.4	.004	60	58	"	450-1/2-5 TPI	450-1/2-5 TPI	160	145
ECC-117	3.3	.004	64	62	"	225-1/0-1½ TPI	225-1/0-1½TPI	140	140
ECC-127	6.4	.007	42	32	"	450-3/2-5 TPI	450-3/2-5 TPI	380	300
ECC-128	6.2	.007	42	32	"	225-1/3-5 TPI	225-1/3-5 TPI	325	250
ECC-158	7.0	.008	64	60	Crow	450-2/2-5 TPI	450-2/2-5 TPI	575	550
ECC-161	14.1	.015	28	16	Plain	450-4/5-5 TPI	450-4/5-5 TPI	700	460
ECC-162	12.0	.015	28	16	"	225-2/5-5 TPI	225-2/5-5 TPI	675	420
X-1549	17.2	.020	21	18	"	225-4/4-5 TPI	225-4/4-5 TPI	770	760
X-1581	5.8	.007	39	34	"	225-1/3-5 TPI	225-1/3-5 TPI	280	250

TABLE VIIc
(Reference Report No. WAL 710/653)

Correlation Between Resistance to Perforation of Fiberglas Samples and Their Yarn and Texture Characteristics

Ballistic Limit (F/S)	Sample	Ends per Inch	Yarn
Cal. .45 (steel-jacketed) Ball Projectiles:			
549	X-1581	39	225-1/3-5 TPI
588	ECC-115	48	225-1/0-1½ TPI
593	ECC-128	42	225-1/3-5 TPI
618	ECC-162	28	225-2/5-5 TPI
647	ECC-127	42	450-3/2-5 TPI
669	X-1549	21	225-4/4-5 TPI
671	ECC-117	64	225-1/0-1½ TPI
698	ECC-112	40	450-1/2-5 TPI
698	ECC-116	60	450-1/2-5 TPI
732	ECC-161	28	450-4/5-5 TPI
738	ECC-138	64	450-2/2-5 TPI
Cal. .22 Fragment-Simulating Projectile:			
956	ECC-162	28	225-2/5-5 TPI
974	ECC-117	64	225-1/0-1½ TPI
988	X-1581	39	225-1/3-5 TPI
1022	X-1549	21	225-4/4-5 TPI
1030	ECC-115	48	225-1/0-1½ TPI
1036	ECC-112	40	450-1/2-5 TPI
1062	ECC-116	60	450-1/2-5 TPI
1062	ECC-127	42	450-3/2-5 TPI
1090	ECC-128	42	225/1/3-5 TPI
1109	ECC-138	64	450/2/2-5 TPI
1188	ECC-161	28	450-4/5-5 TPI

TABLE VIII
(Reference Report No. WAL 710/613)

Summary of Ballistic Tests Conducted at Watertown Arsenal on 6-Ply Glass Webbing Submitted by Russell Manufacturing Company

Sample Tested	Equivalent Steel Thickness	Ballistic Limit G-1-S[1]	G-1-A[2]	G-2[3]	.45[4]
Tautly stretched on rigid wooden frame-back unsupported:					
Glass webbing (6-ply)	.078"	1121	691	1300	766
Nylon Duck (12-ply)	.044"	1105	566	1360	750
Hadfield Steel (Average)	.044"	1050	475	1660	940
Strapped on sawdust-filled canvas dummy:					
Glass Webbing (6-ply)	.079"	1175	---	1360	---
Nylon Duck (11-ply)	.040"	1090	---	1360	---

1. Cal. .30 (34 grain)
2. Cal. .30 (150 grain)
3. Cal. .22 (17 grain)
4. Standard Cal. .45 ball ammunition (steel-jacketed 230 grains)

TABLE IX
(Reference Report No. WAL 710/649)

Summary of Ballistic Tests Conducted at Watertown Arsenal on Samples of 7-Ply Silk Webbing Supplied by Russell Manufacturing Company

Sample Tested	Steel Thickness	Ballistic Limit (F/S) Cal. .45[1]	C-2[2]
Silk Webbing (7-Ply)	.042"	724	1336
Nylon Webbing	.041"	537	1053
Nylon Duck (12-Ply)	.044"	750	1360
Glass Webbing (6-Ply)	.079"	786	1300
Hadfield Steel (Average)	.042"	920	1630

1. Caliber .45 (steel-jacketed) ball projectile - 250 grains.

2. Caliber .22 fragment-simulating projectile - 17 grains.

TABLE X
(Reference Report No. WAL 710/659)

Summary of Penetration Tests Conducted at Watertown Arsenal on Samples of Weinberger Protective Fabric and Its Components

Sample	Equivalent Steel Gauge	Ballistic Limits (F/S) G-1-A[1]	G-1-S[2]	G-2[3]	Cal. .45[4]
Complete Assembly	.040"	488	961	1108	560
4 Plies Corded Component	.046"	---	---	1044	505
3 Plies Corded Component	.034"	---	---	990	474
3 Plies Corded Component (coated with rubber)	.046"	---	---	1028	---
4 Plies Quilting	.068"	---	---	----	735
3 Plies Quilting	.051"	---	---	----	694
2 Plies Quilting	.034"	---	---	1080	613
1 Ply Quilting	.017"	---	---	804	469
For Comparison:					
11 Plies 17½ oz. Nylon Duck	.040"	567	1058	1510	704
Hadfield Manganese Steel	.040"	---	900	1600	900

1. Cal. .30 fragment-simulating projectile - 150 grains.
2. Cal. .30 fragment-simulating projectile - 54 grains.
3. Cal. .22 fragment-simulating projectile - 17 grains.
4. Cal. .45 (steel-jacketed) ball projectile - 230 grains.

TABLE XI

Comparative Resistance to Perforation by Cal. .45 Ball Projectiles of Various Fabric Samples

Material	Equiv. Steel Gauge	Cal. .45 Ballistic Limit	Cal. .45 Figure of Merit*	Reference
11 plies #6 Cotton Duck	.047"	395	41	Table I
4 plies corded component of Weinberger Prot. Fabric	.046"	505	56	Table X
Nylon Belting	.040"	517	57	Table V
Fiberglas (X-1581)	.044"	549	58	Table VIIa
Nylon Belting	.041"	537	59	Table V
Weinberger Protective Fabric	.040"	560	62	Table X
Fiberglas (ECC-115)	.044"	588	63	Table VIIa
Fiberglas (ECC-128)	.044"	593	63	Table VIIa
Fiberglas (ECC-113)	.044"	623	66	Table VIIa
Fiberglas (ECC-162)	.044"	618	66	Table VIIa
Fiberglas (ECC-127)	.044"	647	69	Table VIIa
3 plies quilted component of Weinberger Prot. Fabric	.051"	694	69	Table X
Nylon Parachute Cloth	.044"	656	70	Table IVa
19 ounce unsized Nylon Duck (12 plies)	.039"	629	71	Table III
Fiberglas (ECC-117)	.044"	671	71	Table VIIa
Fiberglas (X-1549)	.044"	669	71	Table VIIa
19 ounce unsized Nylon Duck (14 plies)	.046"	688	72	Table III
Nylon Parachute Cloth	.044"	676	72	Table IVa
Nylon Parachute Cloth	.045"	698	73	Table I
21 plies Fiberglas (Ecc-11-162) plus 1 ply 17½ oz. Nylon Duck with ½" quilting	.045"	697	73	Table VI
19 ounce unsized Nylon Duck (13 plies)	.043"	685	74	Table III
Fiberglas (ECC-112)	.044"	698	74	Table VIIa
Fiberglas (ECC-116)	.044"	698	74	Table VIIa
Fiberglas (ECC-138)	.044"	694	74	Table VIIa

TABLE XI (CONT'D)

Material	Equiv. Steel Gauge	Cal. .45 Ballistic Limit	Cal. .45 Figure of Merit*	Reference
21 plies Fiberglas (ECC-162) plus 1 ply 17½ oz. Nylon Duck with 8-inch quilting	.045"	711	75	Table VI
23 plies Fiberglas (ECC-162) with 2" quilting	.045	710	75	Table VI
Nylon Parachute Cloth	.044"	712	76	Table IXa
21 plies Fiberglas (ECC-162) plus 1 ply 17½ oz. Nylon Duck with 4-inch quilting	.045"	729	77	TTable VI
21 plies Fiberglas (ECC-162) plus 1 ply 17½ oz. Nylon Duck with 1-inch quilting	.045"	738	78	Table VI
11 plies sized 17½ oz. Nylon Duck	.040"	704	78	Table I
Fiberglas (ECC-161)	.044"	732	78	Table VIIa
Fiberglas (ECC-135)	.044"	738	79	Table VIIa
Silk Webbing	.042"	724	79	Table IX
12 plies sized 17½ ounce Nylon Duck	.044"	750	80	Table I
17 plies Fiberglas (ECC-162) plus 3 plies sized 17½ ounce Nylon Duck	.045"	766	80	Table VI

*Figure of merit determined by this formula: $\frac{V_{SUB} \times 100}{V_{HAD}}$ where V_{SUB} is the ballistic limit of the subject sample and V_{HAD} is the characteristic ballistic limit of an equivalent weight of Hadfield manganese steel.

TABLE XII

Comparative Resistance to Perforation by Cal. .22 Fragment-Simulating Projectiles of Various Fabric Samples

Material	Equiv. Steel Gauge	Cal. .22 Ballistic Limit	Cal. .22 Figure of Merit*	Reference
11 plies #6 Cotton Duck	.047"	883**	52	Table I
Fiberglas (ECC-162)	.044"	956	58	Table VIIa
Fiberglas (ECC-117)	.044"	974	59	Table VIIa
Fiberglas (ECC-158)	.044"	988	60	Table VIIa
Nylon Belting	.040"	973	61	Table V
3 plies of corded component of Weinberger Prot. Fabric Coated with Fabric	.046"	1026	61	Table X
4 plies of corded component of Weinberger Prot. Fabric	.046"	1044	62	Table X
Fiberglas (ECC-115)	.044"	1030	62	Table VIIa
Fiberglas (X-1549)	.044"	1022	62	Table VIIa
Fiberglas (ECC-112)	.044"	1036	62	Table VIIa
Fiberglas (ECC-116)	.044"	1062	64	Table VIIa
Fiberglas (ECC-127)	.044"	1062	65	Table VIIa
Nylon Belting	.041"	1053	65	Table V
Fiberglas (ECC-113)	.044"	1101	66	Table VIIa
Fiberglas (ECC-126)	.044"	1090	66	Table VIIa
Fiberglas (ECC-138)	.044"	1106	67	Table VIIa
21 plies Fiberglas (ECC-162) plus 1 ply sized 17½ oz. Nylon Duck with 6" quilting	.045"	1130	67	Table VI
Nylon Belting	.040"	1075**	67	Table V
Nylon Belting	.041"	1085**	67	Table V
21 plies Fiberglas (ECC-162) plus 1 ply sized 17½ ounce Nylon Duck with ½-inch quilting	.045"	1138	68	Table VI
Fiberglas (ECC-135)	.044"	1134	68	Table VIIa
21 plies Fiberglas (ECC-162) plus 1 ply sized 17½ oz. Nylon Duck with 4" quilting	.045"	1146	69	Table VI

TABLE XII (CONT'D)

Material	Equiv. Steel Gauge	Cal. .22 Ballistic Limit	Cal. .22 Figure of Merit*	Reference
Weinberger Protective Fabric	.040"	1106	69	Table X
21 plies Fiberglas (ECC-162) plus 1 ply sized 17½ oz. Nylon Duck with 1" quilting	.045"	1173	70	Table VI
23 plies Fiberglas (ECC-162) with 2" quilting	.045"	1189**	71	Table VI
23 plies Fiberglas (ECC-162) plus 1 ply sized 17½ oz. Nylon Duck with 2"quilting	.049"	1238**	71	Table VI
17 plies Fiberglas (ECC-162) plus 3 plies sized 17½ oz. Nylon Duck with 2"quilting	.045"	1208	72	Table VI
Fiberglas (ECC-161)	.044"	1188	72	Table VIIa
23 plies Fiberglas (ECC-162) plus 1 ply sized 17½oz. Nylon Duck with 2" quilting	.049"	1290	74	Table VI
13 plies unsized 19 ounce Nylon Duck	.043"	1309	80	Table III
14 plies unsized 19 ounce Nylon Duck	.046"	1350	80	Table III
12 plies unsized 19 ounce Nylon Duck	.039"	1283	81	Table III
11 plies sized 17½ ounce Nylon Duck	.040"	1310	82	Table III
12 plies sized 17½ ounce Nylon Duck	.044"	1360	82	Table III
Silk Webbing	.042"	1336	82	Table IX
Nylon Parachute Cloth	.044"	1370	83	Table IVa
11 plies sized 17½ oz. Nylon Duck	.040"	1360**	85	Table I
Nylon Parachute Cloth	.044"	1435	86	Table IVa
Nylon Parachute Cloth	.044"	1435	86	Table IVa
Nylon Parachute Cloth	.045"	1467	88	Table I

*Figure of Merit determined from the formula: $\frac{V_{SUB} \times 100}{V_{MAD}}$, where V_{SUB} is the ballistic limit of the subject sample and V_{MAD} the characteristic ballistic limit of an equivalent weight of Hadfield manganese steel.

**As strapped to a sawdust-filled canvas dummy.

TABLE XIII

Average Figures of Merit for Various Fabrics

With Respect to Their Perforation by Cal. .45 Ball Projectiles

Material	Average Figure of Merit
Nylon [illegible]ck - Sized	79
Fiberglas (ECC-136)	79
Silk Webbing	79
Nylon Parachute Cloth	73
Nylon Duck - Unsized	72
Weinberger Protective Fabric - Quilted Element	69
Weinberger Protective Fabric - Complete	62
Nylon Belting	58
Weinberger Protective Fabric - Corded Element	56
Cotton Duck	41

TABLE XIV

Average Figures of Merit for Various Fabrics With Respect to Their Perforation by Cal. .22 Fragment-Simulating Projectiles, S-2

Material	Average Figure of Merit
Nylon Parachute Cloth	85
Nylon Duck - Sized	82
Silk Webbing	82
Nylon Duck - Unsized	80
Fiberglas (ECC-161)	72
Weinberger Protective Fabric - Complete	69
Nylon Belting	63
Weinberger Protective Fabric - Corded Element	62
Weinberger Protective Fabric - Rubber-coated Corded Element	61
Cotton Duck	52