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WATERTOWN ARSENAL  
LABORATORY

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MEMORANDUM REPORT

NO. WAL 710/732

Resistance of Various Plastic Laminates, Made by Victory Plastics Co.,  
to Perforation by Fragment-Simulating Projectiles

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BY  
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DATE 22 March 1945

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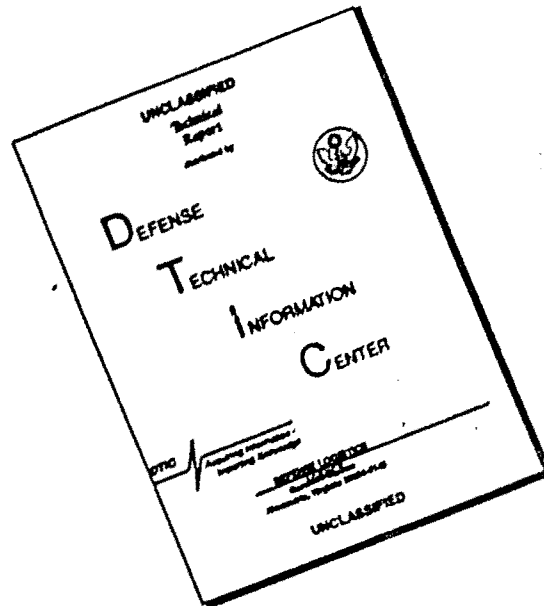
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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/732

Partial Report on Problem B-8.14

22 March 1945

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Resistance of Various Plastic Laminates, Made by Victory Plastics Co.,  
to Perforation by Fragment-Simulating Projectiles

1. In response to a request from the Office, Chief of Ordnance, a program ~~has been~~ <sup>was</sup> conducted at ~~this~~ <sup>the</sup> arsenal to develop improved components of body armor assemblies. In accordance with a request of the Boston Ordnance District, tests ~~have been~~ <sup>were</sup> conducted here on samples of plastic laminates made by the Victory Plastic Company. Inasmuch as such materials have been considered as components of body armor assemblies it is considered desirable to report the results of these tests as part of the general development program.

~~2.~~ None of the materials submitted exhibited resistance to perforation by fragment-simulating projectiles equivalent to that afforded by samples of Doron<sup>3</sup> tested earlier. The smallness of most samples did not allow quantitative comparison of the various samples.

3. After determination of its weight-per-unit-area, each sample was rigidly clamped to an appropriate frame which allowed the areas of impact to be free of support from the rear. Into these areas were directed impacts of cal. .45 steel-jacketed projectiles or cal. .30 fragment-simulating projectiles, G-1-S,<sup>4</sup> or cal. .22 fragment-simulating projectiles, G-2,<sup>5</sup> depending upon the size of the sample and the availability of the projectiles. On the basis of weight-per-unit-area a standard of required resistance was established for each sample by reference to the earlier tests of Doron. Since the extreme smallness of many of the samples made the determination of ballistic limits

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1. O.O. 422.3/71(c) - Wtn 470.5/7443(c), 28 September 1943.
  2. BTN 160/3954/47482 - Wtn 400.112/3722, 14 December 1944.
  3. WAL 710/641, 25 May 1944.
  4. WAL 762/247(c), 17 December 1943.
  5. WAL 762/253(c), 7 January 1944.

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impossible, charges calculated to give the required velocity were prepared and fired, and the resistance of the sample was thus determined qualitatively. The results of the tests are recited in Table I.

4. Although this method did not allow an absolute evaluation of the many samples submitted, it did provide, in most cases, a basis on which a decision as to whether or not the material was better than materials already in use could be made. On this basis, therefore, it can be said that all materials submitted, with the exception of samples 101944A, 103144A, 11344A, 11545A, appeared to be inferior in resistance to perforation by fragment-simulating projectiles to materials tested previously. Of these exceptions the status of sample 11344A alone has been quantitatively determined. This sample appeared to afford resistance to the cal. .45 projectile substantially equivalent to that of Deron. The results on the other three exceptions were such as to preclude any definite decision as to their merits.

5. Results of tests conducted on various materials in the past have indicated a lack of correlation between the relative resistance of different materials under test with fragment-simulators and their relative resistance to perforation by fragments of a high-explosive shell statically detonated in close proximity to the samples. Such indications caution against extrapolation of ballistic limit test results to service conditions. It is recognized that the only valid test currently employed to reflect service conditions is an actual fragmentation test. Ballistic limit tests such as those performed during this program have a valid role in that they can determine the control being exercised by the manufacturer in a continuous or repetitive process of fabricating a material which has previously established its resistance efficiency in an actual fragmentation test. Within certain limitations they also may be used to determine the probable resistance to actual fragmentation of a novated version of a material whose resistance has already been established. They should never be used, however, as a basis for determining the merits of a material which, either in itself or in some similar form, has not previously been tested.

6. Since the materials used in the subject tests are for the most part modifications of materials tested earlier, it is believed that the use of fragment-simulators as determinators of the merits of these materials has been legitimate. The next step would appear to be the fabrication of enough samples of the type 11344A to allow an actual fragmentation test. From the results of the subject tests no other samples appear to warrant the additional expenditure of time, manpower, materials and money which such a test requires.

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TABLE I

Summary of Ballistic Test Results on Samples of Plastic Laminates

Prepared by Victory Plastics Co.

Make-Up of Sample	Sample size	Sample weight (Grams)	Surviv. weight steel (Grams)	Ballistic Limit	Ballistic Limit	
					Req. act.	Req. act.
11 ply Fiberglass ECC-11-164 coated with 6B Nylon. 11 ply Hi/ten Rayon 2 oz. alternate layers. Coated with 6B Nylon solution, molded at 1500 lbs. per sq. in. for 15 min. at 320 F.	10" x 10" x 3/4"	26.0	.029"	760	<975	G-2
14 ply Fiberglass ECC-11-164 coated with 6B Nylon. 14 ply Nylon 6 oz. alternate layers, coated with 6B Nylon, molding pressure 1500 lbs. per sq. in. for 45 min. at 320 F.	10" x 10" x 3/4"	16.0	.047"	1120	<860	
14 ply Fiberglass ECC-11-164 coated with 6B Nylon. 14 ply Hi/ten Rayon 2 oz. alternate layers coated with 6B Nylon, molding pressure 1500 lbs. per sq. in. for 30 min. at 320 F.	10" x 10" x 3/4"	15.0	.074"	860	775-790	
15 ply Fiberglass ECC-11-164 coated with 6B Nylon. 5 ply Hi/ten Rayon 2 oz. alternate layers in back of sample, coated with 6B Nylon. Molding pressure 1500 lbs. per sq. in. for 30 min. at 320 F.	10" x 10" x 3/4"	12.0	.041"	1300	<865	
13 ply Fiberglass ECC-11-164 coated with 6B Nylon. 6 ply Nylon 6 oz. alternate layers in back portion of sample. Coated with 6B Nylon, molding pressure 1500 lbs. per sq. in. for 30 min. at 320 F.	10" x 10" x 3/4"	17.0	.061"	1000	<855	
15 ply Fiberglass ECC-11-164 coated with 6B Nylon. 5 ply Hi/ten Rayon 2 oz. alternate layers in back portion of sample. Coated with 6B Nylon, molding pressure 1000 lbs. per sq. in. for 30 min. at 320 F.	10" x 10" x 3/4"	16.0	.041"	960	<845	
14 ply Fiberglass ECC-11-164. Both fabrics coated with Gelva 15. 14 ply Nylon 6 oz. alternate layers. Molding pressure 200 lbs. per sq. in. for 30 min. at 320 F.	10" x 10" x 3/4"	15.0	.036"	1300	<915	
14 ply Fiberglass ECC-11-164. Both fabrics coated with Gelva 15. 14 ply Nylon 6 oz. alternate layers. Molding pressure 200 lbs. per sq. in. for 30 min. at 320 F.	10" x 10" x 3/4"	17.0	.041"	1000	890-880	

102544B	14 ply Fiberglass ECC-11-164. Both fabrics coated with Gelta-15. 14 ply Hi/ten Rayon 2 oz. alternate layers. Molding pressure 200 lbs. per sq. in. for 30 min. at 320 F.	47.0	.041"	--	1000 890+80	--
102544C	14 ply Fiberglass ECC-11-164. Both fabrics coated with Gelta-15. 14 ply Hi/ten Rayon 2 oz. alternate layers. Molding pressure 200 lbs. per sq. in. for 30 min. at 320 F.	47.0	.041"	--	1000 840 App.	--
102744A	14 ply Fiberglass ECC-11-164. Heated in oven 2 hrs. at 400 F. and coated with 6B Nylon. Molding pressure 100 lbs. per sq. in. for 30 min. at 320 F.	32.0	.033"	--	840 <840	--
102744B	Same as 102744A except the Fiberglass was not heat treated and the molding pressure reduced to 150 lbs. per sq. in.	39.0	.034"	--	860 <785	--
102744C	Same as 102744B except the molding pressure was reduced to 125 lbs. per sq. in.	33.5	.033"	--	840 <790	--
102744D	Same as 102744B and C except the molding pressure was increased to 200 lbs. per sq. in.	38.0	.033"	--	840 <780	--
102744E	14 ply Fiberglass ECC-11-164. No heat treatment. 14 ply Vinylite (C.OO4") alternate layers, molding pressure 200 lbs. per sq. in. for 30 min. at 320 F.	44.0	.038"	--	940 845+35	--
102744F	Same as 102744E except the molding pressure was reduced to 150 lbs. per sq. in.	43.0	.037"	--	920 863+18	--
103144A	17 ply Fiberglass X-1551. 17 ply Vinylite (C.OO4") alternate layers, molding pressure 500 lbs. per sq. in. for 30 min. at 310 F.	261	.036"	910 >899	--	--
103144B	Same as 103144A except molding pressure was reduced to 250 lbs. per sq. in.	256	.035"	910 804+24	--	--
103144C	3 ply Duck (O.O80"). 4 ply Tenite II 85. alternate layers, molding pressure 500 lbs. per sq. in. for 15 min. at 320 F.	334	.045"	1050 <512	--	--
103144D	5 ply Duck (O.O80"). 5 ply Vinylite alternate layers, molding pressure 500 lbs. per sq. in. for 30 min. at 300 F. (O.OO4").	--	.042"	1000 <514	--	--
103144E	Same as 103144D except 3 plys of each were used in place of alternate layers of 5 each.	269	.037"	950 <509	--	--
11344A	25 ply Fiberglass X-1551. 25" Vinylite (C.OO4") alternate layers, molding pressure 650 lbs. per sq. in. for 30 min. at 320 F.	385	.052"	1130 1108	--	--
11344B	22 ply Fiberglass X-1551. 22 ply Vinylite	350	.047"	1065 1000	--	--

1144G	sq. in. for 30 min. at 300 F. (0.0047). Same as 103144F except 3 plys of each were used in place of alternate layers of 5 each.	7-1/8"x7-1/2"	269	.037"	350	<509	--	--	--
1144A	25 ply Fiberglass X-1551. 25" Vinylite (0.004") alternate layers, molding pressure 650 lbs. per sq. in. for 30 min. at 320 F.	7.6"x7.6"	385	.092"	1130	1108	--	--	--
1144B	22 ply Fiberglass X-1551. 22 ply Vinylite (0.004") alternate layers. Molding pressure 500 lbs. per sq. in. for 30 min. at 320 F.	7.6"x7.6"	350	.047"	1065	1000	--	--	--
1144C	21 ply Fiberglass 200-128-38. 21 ply Butvar (0.015") alternate layers. Molding pressure 650 lbs. per sq. in. for 15 min. at 330 F.	8"x8"	168	.052"	1130	<1105	--	--	--
1144D	40 ply Fiberglass 200-128-38 coated with 10% T19 F. V. Butyral on both sides. Penetration complete. Molding pressure 500 lbs. per sq. in. for 30 min. at 275 F.	8"x8"	350	.043"	--	--	--	--	1410 1073+53
1144E	23 ply Fiberglass 200-128-38. 23 ply Saran screen (Velon), alternate layers. Molding pressure 500 lbs. per sq. in. for 35 min. at 340 F.	8"x8"	352	.043"	--	--	--	--	1410 <1085
1145A	24 ply Fiberglass 200-128-38. 2 ply Styron (H.V.) alternate plys of styron between the 17th and 19th ply of Fiberglass. Molding pressure 500 lbs. per sq. in. for 30 min. at 270 F.	8"x8"	283	.034"	--	--	--	--	1130 952+48
1145B	20 ply Fiberglass 200-128-38. 2 ply Emery cloth No. 40. 21 ply Butvar (0.015") Emery cloth placed in alternate layers starting from the 14th ply of Butvar and Fiberglass. Molding pressure 250 lbs. per sq. in. for 30 min. at 280 F.	7"x7"	406	.064"	--	--	--	--	1830 1350
1145A	22 ply X-1551 Fiberglass coated with a Vinyl dispersion. Molding pressure 500 lbs. per sq. in. for 10 min. at 340 F.	8"x8"	359	.044"	1030	>958	--	--	--
1145B	15 ply X-1551 Fiberglass coated with a Vinyl dispersion. 7 ply Rayon coated with a Vinyl dispersion alternate layers in center portion of sample; molding pressure 250 lbs. per sq. in. for 5 min. at 340 F.	8"x8"	359	.044"	1030	<828	--	--	--
1145C	19 ply X-1551 Fiberglass coated with Vinyl dispersion. 9 ply Butvar (0.005") alternate layers in center portion of sample; molding pressure 250 lbs. per sq. in. for 10 min. at 340 F.	8"x8"	353	.043"	1015	<825	--	--	--
1145D	Same as 1145A except the molding pressure was reduced to 100 lbs. per sq. in. for 5 min. at 340 F.	8"x8"	375	.046"	1050	824+23	--	--	--
1145E	20 ply X-1551 Fiberglass - no coating. 10 ply Butvar (0.005") alternate layers; molding pressure 100 lbs. per sq. in. for 5 min. at 340 F.	8"x8"	332	.040"	990	<809	--	--	--
		12"x11-1/2"	846	.048"	1075	860 Face 875 Rear	--	--	--



Molding pressure 100 lbs. per sq. in. for 30 min. at 280 F.

11545A	20 ply X-1551 Fiberglass coated with a Vinyl dispersion. Molding pressure 500 lbs. per sq. in. for 10 min. at 340 F.	2"x3"	359	.044"	1030	>958	--	--	--
11545B	15 ply X-1551 Fiberglass coated with a Vinyl dispersion. 7 ply Rayon coated with a Vinyl dispersion alternate layers in center portion of sample; molding pressure 250 lbs. per sq. in. for 5 min. at 340 F.	8"x8"	359	.044"	1030	<828	--	--	--
11545C	19 ply X-1551 Fiberglass coated with Vinyl dispersion. 3 ply Butvar (0.005") alternate layers in center portion of sample; molding pressure 250 lbs. per sq. in. for 10 min. at 340 F.	8"x3"	353	.043"	1015	<825	--	--	--
11545D	Same as 11545A except the molding pressure was reduced to 100 lbs. per sq. in. for 5 min. at 340 F.	8"x3"	375	.046"	1050	224+23	--	--	--
11545E	20 ply X-1551 Fiberglass - no coating. 15 ply Butvar (0.005") alternate layers; molding pressure 100 lbs. per sq. in. for 5 min. at 340 F.	8"x8"	332	.040"	990	<809	--	--	--
12445A-1	22 ply X-1551 Fiberglass, coated with Vinyl dispersion. Molding pressure 600 lbs. per sq. in. for 15 min. at 340 F.	12"x11-1/2"	846	.048"	1075	860 Face 875 Rear	--	--	--
12445A-2	" " " " " " " "	12"x12"	872	.047"	1065	820	--	--	--
12445A-3	" " " " " " " "	12"x12"	890	.048"	1075	821	--	--	--
12445B-1	Same as 12445A except molding pressure was increased to 800 lbs. per sq. in.	12"x12"	875	.047"	1065	801	--	--	--
12445B-2	" " " " " " " "	12"x12"	894	.048"	1075	848	--	--	--
12445B-3	" " " " " " " "	12"x12"	891	.048"	1075	817	--	--	--
12445C-1	Same as 12445A and B except molding pressure was increased to 1000 lbs. per sq. in.	12"x12"	887	.048"	1075	827	--	--	--
12445C-2	" " " " " " " "	12"x12"	895	.048"	1075	862	--	--	--
12445C-3	" " " " " " " "	12"x12"	836	.048"	1075	819	--	--	--
12445C-4	" " " " " " " "	12"x12"	891	.048"	1075	839	--	--	--
12445C-5	" " " " " " " "	12"x12"	882	.048"	1075	812	--	--	--
12445C-6	" " " " " " " "	12"x12"	876	.047"	1065	817	--	--	--

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1. Cal..45 steel-jacketed ball projectile - 270 grains
2. Cal..30 fragment-simulating projectile - 14 grains
3. Cal..22 fragment-simulating projectile - 17 grains

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