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WATERTOWN, MASS.

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/706

710/706

Resistance of Various Proposed Components of Flak-Curtains to Perforation by Flak-Simulating Projectiles

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DATE 29 December 1944

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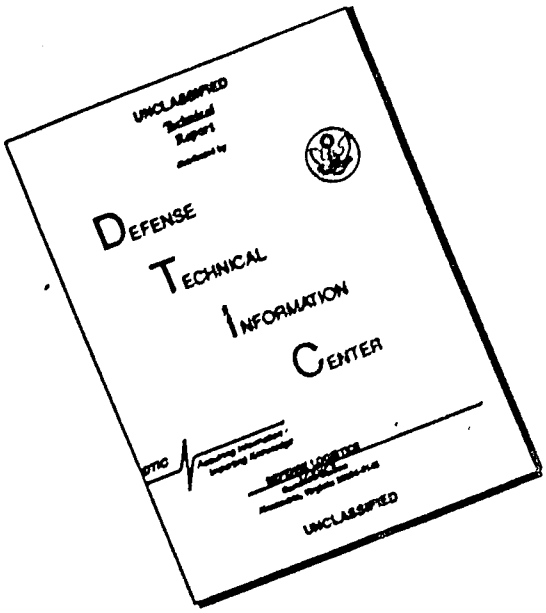

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/706

First and Final Report on Problem B-3.3

22 December 1944

Resistance of Various Proposed Components of Flak-Curtains

to Perforation by Flak-Simulating Projectiles

1. As a result of a request from the Office, Chief of Ordnance[1], a program of investigation of various materials proposed as components of flak-resistant curtains has been conducted at this arsenal over the past several months.

2. As originally contemplated, this program would have included the development of a projectile which would simulate reproducibly and measurably the impact of fragments of high-explosive anti-aircraft shell. Indeed, a projectile similar in design to the cal. .22 fragment-simulating projectile, G-2[2], has been tested. However the lack of correlation between the results of actual fragmentation tests of 20mm. high-explosive projectiles and the results of tests with the cal. .22 projectile or any other single projectile has led to an abandonment of the contention that any one projectile may be developed which may reproducibly and measurably simulate the effect of service impact of high-explosive shell fragments against all materials.

3. Nevertheless several materials have been tested at this arsenal with various projectiles and the results of these tests may be of some use in the formation of an opinion as to the relative resistance characteristics of these materials to the attack of fragments of high-explosive anti-aircraft shell. It is the purpose of this report to present these results.

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1. O.O. 470.1/39784 - Wtn 470.1/7415 - 10 May 1944.

2. WAL 7[illegible]/263

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A-1

4. Hadfield manganese steel of the standard composition and a Hadfield manganese steel containing 3% nickel were tested as were several ferritic steels and aluminum alloys. The results of these tests as well as other data pertaining to the tested materials are included in Table I.

5. In earlier tests in which similar projectiles were fired against materials of a lighter gauge (.040" to .050") Hadfield manganese steel has consistently exhibited resistance characteristics superior to those of other materials. In the present tests this superiority is maintained in the lighter gauges (around .060") but is relinquished when the gauges become greater. The relative resistance of these materials to attack with fragments of larger high-explosive shell may, however, not follow this trend. The inversion of relative superiority of the austenitic and ferritic steels as the gauge increases is believed attributable to the fact that the e/d relationship is changing rapidly since the projectile diameter is constant. It is believed that were the e/d ratio to remain constant, the relative resistance of the materials involved would not vary.

6. The lack of correlation between the results of tests of materials under actual fragmentation of 20mm. high-explosive shell and the results of tests with fragment-simulators has been referred to above. Technical difficulties militate against a practical evaluative test of materials under actual fragmentation of high-explosive shell of larger caliber. There can, therefore, not be determined accurately whether any correlation exists between the results of the subject tests and service conditions.

7. It is therefore suggested that the results of actual fragmentation tests with 20mm. high-explosive shell be used as a basis for the evaluation of materials proposed as components of flak-resistant curtains as well as for the evaluation of materials proposed as components of body armor assemblies. It is contended that the fragmentation pattern of larger caliber shell may not vary greatly from that of the evaluable 20mm. shell and that the relative resistance of materials at any given ratio of e/d should not vary greatly provided the manner of presentation of the projectile remains fairly constant.

J. F. Sullivan

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Asst. Engineer

APPROVED:

E. L. Reed

E. L. REED
Research Metallurgist
Acting Chief, Armor Section

										Ballistic Limit			
	C	[illegible]	[illegible]	[illegible]	[illegible]	Cr	Mo	Hardness	[illegible]	[illegible][1]	G-2[2]	Ball[3] .30	Carb.[4] .30
	Hadfield Manganese Steel (W/3% Ni)							91Rb	.058"	—	—	1194	[illegible]
	"	"	"	"				88Rb	.058"	—	—	120[illegible]	[illegible]
	"	"	"	"				87Rb	.059"	—	—	1195	[illegible]
	"	"	"	"				89Rb	.059"	—	—	122[illegible]	[illegible]
	"	"	"	"				90Rb	.059"	—	—	1215	[illegible]
	"	"	"	"				86Rb	.059"	—	—	1181	[illegible]
	"	"	"	"				36Rb	.060"	—	—	1168	[illegible]
	"	"	"	"				92Rb	.060"	—	—	125[illegible]	[illegible]
	Regular Hadfield Manganese Steel							89Rb	.063"	1266	—	1270	[illegible]
	"	"	"	"				87Rb	.063"	—	—	12[illegible]5	[illegible]
	.23	1.19	.19	.020	.017	—	—	.33	(53Rc)[a]	.063"	—	—	11[illegible]	[illegible]
	.23	1.19	.19	.020	.017	—	—	.33	(41Rc)[b]	.063"	—	—	1095	[illegible]
	.23	1.19	.19	.020	.017	—	—	.33	(38Rc)[c]	.063"	—	—	1068	[illegible]
	[illegible]	1.19	.19	.020	.017	—	—	.33	(40Rc)[d]	.063"	—	—	1071	[illegible]
	.29	.73	.25	.028	.018	.4	.52	.17	48Rc[e]	.064"	928	—	—	—
	.29	.47	.28	.025	.017	—	.93	.20	49Rc[f]	.065"	1145	—	—	—
	Aluminum Alloy 24ST								—	.065"	—	—	1292	[illegible]
	Regular Hadfield Manganese Steel								—	.066"	—	—	1325	[illegible]
	Aluminum Alloy R-301-W								—	.067"	1110	—	—	—
	"	"	"						—	.067"	1098	—	—	—
	"	"	"						—	.067"	—	1082	—	

[illegible] 188	[illegible]												—	—
188	[illegible]												—	—
188	[illegible]												—	—
178	[illegible]												—	—
198	[illegible]												—	—
178	[illegible]												—	—
[illegible]	[illegible]											—	1344	[illegible]
[illegible]	[illegible]											—	—	[illegible]
[illegible] .5	Aluminum [illegible] between V-board											[illegible]	—	—
[illegible] .5	[illegible]											1620	—	—
[illegible] 20	[illegible]											1313	—	—
[illegible]	Aluminum [illegible] between V-board									[illegible]		1805	—	—
[illegible]	[illegible]								—	.072"	937	—	—	—
[illegible]	[illegible]									.072"	940	—	—	—
[illegible]	[illegible]									[illegible]		1463	—	—
[illegible]	[illegible]									[illegible]		1570	—	—
[illegible]	[illegible]									[illegible]		1440	—	—
[illegible]	[illegible]								—	[illegible]	[illegible]	—	—	—
[illegible]	[illegible]								—	.074"	980	—	—	—
	.29	.87	.28	.025	.017	—	.93	.20	[illegible]	.076"	—	—	1518	[illegible]
	.29	.87	.28	.025	.017	—	.93	.20	[illegible]	.077"	—	—	[illegible]	—
	Regular Hadfield Manganese Steel								89Rb	.079"	—	—	1498	[illegible]
[illegible]	Fiberglass Belting								—	.079"	786	1300	—	—
[illegible]	Regular Hadfield Manganese Steel								89Rb	.080"	—	—	—	[illegible]
[illegible]	Hadfield Manganese Steel (w/3% Ni)								94Rb	.080"	—	—	1471	[illegible]
	"	"	"	"					94Rb	.080"	—	—	1470	[illegible]
	"	"	"	"					92Rb	.080"	—	—	[illegible]	[illegible]
	.24	1.50	.20	.016	.018	—	—	.31	(38Rc)[i]	.080"	—	—	[illegible]	[illegible]
	Hadfield Manganese Steel (w/3% Ni)								90Rb	.081"	—	—	[illegible]	[illegible]
	"	"	"	"					92Rb	.081"	—	—	[illegible]	
	"	"	"	"					91Rb	.081"	—	—	[illegible]	[illegible]
	.24	1.50	.20	.016	.018	—	—	.31	(53Rc)[j]	.081"	—	—	[illegible]	[illegible]
	.24	1.50	.20	.016	.018	—	—	.31	(41Rc)[k]	.081"	—	—	1395	[illegible]

(3)

15-														
15-6														
16-2														
GT-5														
GT-6														1468
15-4													1490	1530
15-5													1529	1525
-7													1407	1483
-5													1268	1343
-.020"												1590	—	—
505													899	—
505													1511	—
-2													1485	1458
250													—	1443
250												1740	—	—
250													—	1498
TA 250													—	1405
50													—	1418
													1523	1543
.29				.017									—	1805
.29												1261	—	1490
				Aircraft Composition									1616	1885
				.018		.52	.17						—	2000
				.018		.52	.17						—	1555
				Manganese Steel									1848	18 8
.27			.018	.016	—	—	.51						2060	1950
.27			.018	.016	—	—	.51						—	2217
.27			.018	.016	—	—	.51						2040	2043
				Alloy 24ST									1593	1639
				Jessop Steel Co. Aircraft Composition									1939	[illegible]
.27	1.80	.21	.018	.016	—	—	.51						1981	[illegible]
.27	1.80	.21	.018	.016	—	—	.51						1993	[illegible]
.27	1.80	.21	.018	.016	—	—	.51						1969	173
.27	1.80	.21	.018	.016	—	—	.51							

H86505	.29	.73	.25	.028	.018	.46	.52	.17	50Rc [r]	.112"	—	—	—	2000
H86505	.29	.73	.25	.028	.018	.46	.52	.17	21Rc [r]	.114"	—	—	—	1555
[illegible]-3	Regular Hadfield Manganese Steel								—	.119"	—	—	1848	1868
FJ-7	.27	1.80	.21	.018	.016	—	—	.51	(41Rc) [s]	.126"	—	—	2060	1950
FJ-11	.27	1.80	.21	.018	.016	—	—	.51	(46Rc) [t]	.129"	—	—	—	2217
[illegible]	.27	1.80	.21	.018	.016	—	—	.51	(37Rc) [u]	.130"	—	—	2040	2043
[illegible]-7	Aluminum Alloy 24ST								—	.130"	—	—	1597	1939
[illegible]	Jessop Steel Co. Aircraft Composition								(153BH)	.131"	—	—	1939	[illegible]
[illegible]	.27	1.80	.21	.018	.016	—	—	.51	(4[illegible]Rc) [v]	.131"	—	—	1981	[illegible]
[illegible]	.27	1.80	.21	.018	.016	—	—	.51	([illegible]Rc) [w]	.132"	—	—	1993	[illegible]
FJ-17	.27	1.80	.21	.018	.016	—	—	.51	(41Rc) [x]	.132"	—	—	1969	173
[illegible]	.27	1.80	.21	.018	.016	—	—	.51	(37Rc) [y]	.13[illegible]"	—	—	1832	[illegible]
[illegible]	.27	1.80	.21	.018	.016	—	—	.51	(47Rc) [z]	.132"	—	—	2019	[illegible]
[illegible]	.27	1.80	.21	.018	.016	—	—	.51	(37Rc) [aa]	.13[illegible]"	—	—	1851	1987
[illegible]-8	.27	1.80	.21	.018	.016	—	—	.51	(38Rc) [bb]	.133"	—	—	195[illegible]	2058
[illegible]-7	.27	1.80	.21	.018	.016	—	—	.51	([illegible]Rc) [cc]	.134"	—	—	1888	060
[illegible]	.27	1.80	.21	.018	.015	—	—	.51	([illegible]Rc) [dd]	.134"	—	—	1998	[illegible]
[illegible]	.27	1.80	.21	.018	[illegible]	—	—	.51	([illegible]Rc) [ee]	.135"	—	—	1[illegible]	[illegible]
[illegible]	.27	1.80	.21	[illegible]	[illegible]	—	—	.51	([illegible]Rc) [ff]	.13[illegible]"	—	—	[illegible]48	[illegible]
[illegible]	.27	1.80	.21	[illegible]	[illegible]	—	—	.51	([illegible]Rc) [gg]	.13[illegible]"	—	—	[illegible]	[illegible]
[illegible]	.9	.7	.8	[illegible]	[illegible]	—	[illegible]	.20	12[illegible]Rc [hh]	.15[illegible]"	—	—	77[illegible]	—
[illegible]	.9	.7	.8	[illegible]	[illegible]	—	[illegible]	.20	1[illegible]Rc [ii]	.151"	—	—	[illegible]	[illegible]
[illegible]-1	Regular [illegible] Manganese Steel								—	.15[illegible]"	—	—	[illegible]	[illegible]
[illegible]10	.9	.75	[illegible]	[illegible]	[illegible]	.50	[illegible]	.20	50Rc [jj]	.156"	—	—	[illegible]	[illegible]
[illegible]10	.9	.75	[illegible]	[illegible]	[illegible]	.50	[illegible]	.20	[illegible]1Rc [kk]	.158"	—	—	[illegible]	—

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FOOTNOTES TO TABLE I

1. Cal. .45 steel-jacketed ball projectile.
2. Cal. .22 fragment-simulating projectile, G-2.
3. Cal. .30 Ball M2 projectile.
4. Cal. .30 Carbine ball M1 projectile.

a. Hardness reported by company after quenching in oil at 125°F. after reheat at 1600°F.
b. Hardness reported by company after tempering 1 hour at 600°F. following quench recited in note a.
c. Same after tempering 1 hour at 800°F.
d. Same after tempering 1 hour at 700°F.
e. Heat treated at W.A. as follows: 1600°F. - 10 min. - oil; 300°F. - 1 hr.-air.
f. Same as e.
g. Same as e.
h. As rolled.
i. Same as c.
j. Same as a.
k. Same as b.
l. Same as d.
m. As rolled.
n. Same as e.
o. Same as e.
p. As rolled.
q. Same as e.
r. As rolled.
s. Same as b.
t. Hardness reported by company after austempering in salt bath at 450°F.
u. Same as c.
v. Hardness reported by company after quenching in oil from 1600°F. followed by tempering at 300°F. for 2 hours.
w. Hardness reported by company after austempering in salt bath at 500°F.
x. Hardness reported by company after austempering in salt bath at 600°F.
y. Hardness reported by company after austempering in salt bath at 700°F.
z. Hardness reported by company after austempering in agitated salt bath at 500°F.

aa. Hardness reported by company after quenching in oil from 1600°F. followed by tempering for 1 hour at 800°F.
bb. Hardness reported by company after quenching in oil from 1600°F. followed by 4 hour sub-zero transformation, then tempered for 1 hr. at 800°F.
cc. Same as bb except tempering temperature 700°F.
dd. Hardness reported by company as oil-quenched from 1600°F.
ee. Hardness reported by company after quenching in oil from 1600°F. followed by tempering for 1 hour at 700°F.

FOOTNOTES TO TABLE I (cont.)

ff. Hardness reported by company after quenching in oil from 1600°F. followed by 4 hour sub-zero transformation.
gg. Same as ff, followed by 1 hour temper at 300°F.
hh. As rolled.
ii. Same as e.
jj. Same as e.
kk. As rolled.