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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/702

Resistance of Variously Heat-Treated Samples of Ni-Mo and Si-Cr-Mo-Zr Steels to Perforation by Fragment-Simulating Projectiles

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BY

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DATE 21 October 1944

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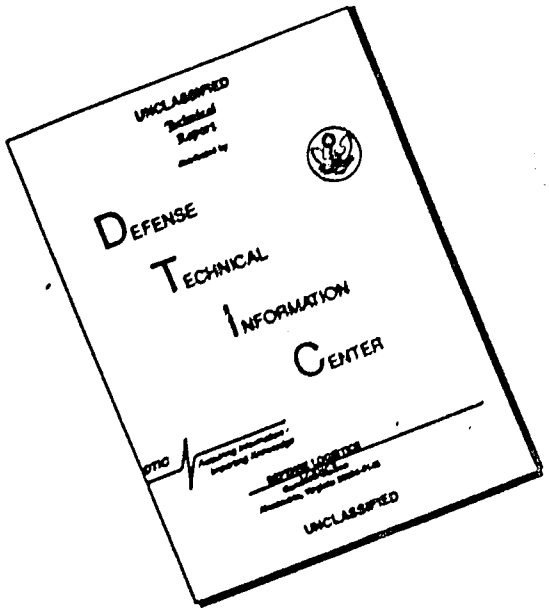

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/702

Twenty-Fourth Partial Report on Problem B-8.2

21 October 1944

Resistance of Variously Heat-Treated Samples of Ni-Mo and Si-Cr-Mo-Zr Steels to Perforation by Fragment-Simulating Projectiles

1. At the request of the Office, Chief of Ordnance[1], tests have recently been conducted ~~at this arsenal~~ to determine the resistance of variously heat-treated samples of nickel-molybdenum and silicon-chromium-molybdenum-zirconium steels to perforation by fragment-simulating projectiles.

2. Although the resistance of the as-quenched samples of the silicon-chromium-molybdenum-zirconium steel as well as that of samples of the same composition drawn at 300°F. was considerably better than that of the other samples tested, it did not begin to compare with the resistance provided by an equivalent weight of Hadfield manganese steel under impact of the same types of projectiles.

3. Samples of each composition as heat-treated by seven different methods were clamped rigidly to wooden ballistic frames and impacted in unsupported areas with cal. .45 steel-jacketed ball projectiles and with fragment-simulating projectiles G-1-A, G-1-S[2] and G-2[3], developed at this arsenal. The results are recited in Table I along with hardness and thickness determinations made here.

4. The discrepancy between the ladle carbon and the final carbon content of the Ni-Mo steel indicative of decarburization, is undoubtedly connected with the generally low resistance of samples of this composition as compared with that of samples of the other composition.

5. Apparently little or no correlation exists between the hardness of these samples and their resistance to perforation by the various projectiles used. The

1. O.O. 470.1/41527 - Wtn. 470.1/54, 18 September 1944.
2. WAL 762/247(c)
3. WAL 762/253(c)

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great variance in the hardness of samples of the same composition with identical nominal heat-treatment reflects poor control of the heat-treatment processes.

6. The results of these tests offer further corroboration to the contention that, in the range of weight-per-unit-area currently under consideration for use in body armor, the resistance afforded by Hadfield manganese steel of good quality cannot be equalled by that of any other steel.

J. F. Sullivan
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APPROVED:

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TABLE I

Summary of Ballistic Tests Conducted at Watertown Arsenal on Samples of Ni-Mo and Si-Cr-Mo-Zr Steels Submitted by The American Rolling Mill Company

Sample No.	Heat-Treatment	Hardness (Rc)	Actual Gauge	Ballistic Limit .45[1]	Ballistic Limit G-2[2]	Ballistic Limit G-1-A[3]	Ballistic Limit G-1-S[4]
11-1	As quenched in oil from 1450°F.	34	.049"	514	—	-	-
11-2	"	39	.047"	-	1030	378	825
12-1	Oil quenched from 1450°F, drawn at 300°F.	35	.048"	488	—	-	-
12-2	"	40	.047"	-	1155	403	753
13-1	Oil quenched from 1450°F, drawn at 600°F.	35	.050"	438	—	-	-
13-2	"	37	.047"	-	1045	383	778
14-1	Oil quenched from 1450°F, drawn at 900°F.	26	.048"	446	—	-	-
14-2	"	28	.048"	-	950	345	917
15-1	Oil quenched from 1450°F, drawn at 1200°F.	20	.049"	500	—	-	-
15-2	"	20	.049"	-	893	370	740

Chemical Composition

C	Mn	Si	P	S	Ni	Cr	Mo	Zr	Cu
.10*	.54	.24	.012	.021	3.84	—	.34	—	.24

TABLE I (Cont'd)

Sample No.	Heat-Treatment	Hardness (Rc)	Actual Gauge	Ballistic Limit .45[1]	G-2[2]	G-1-A[3]	G-1-S[4]
16-1	Normalized from 1650°F.	18	.048"	568	—	-	—
16-2	"	17	.048"	-	1085	391	785
17-1	Quenched from 1450°F into salt bath at 575°F. for 10 minutes.	29	.049"	487	—	-	—
17-2	"	31	.049"	-	935	396	820

Chemical Composition

C	Mn	Si	P	S	Ni	Cr	Mo	Zr	Cu
.25	.88	.81	.019	.021	—	.82	.14	.14	.064

21-1	As quenched in oil from 1650°F.	45	.049"	689	—	-	—
21-2	"	44	.047"	-	1660	480	1050
22-1	Oil quenched from 1650°F., drawn at 300°F.	46	.048"	537	—	-	—
22-2	"	44	.045"	-	1685	423	975
23-1	Oil quenched from 1650°F., drawn at 600°F.	43	.049"	579	—	-	—
23-2	"	41	.047"	-	1305	500	948
24-1	Oil quenched from 1650°F., drawn at 900°F.	36	.049"	489	—	-	—
24-2	"	35	.046"	-	1097	470	828
25-1	Oil quenched from 1650°F., drawn at 1200°F.	20	.049"	539	—	-	—
25-2	"	23	.047"	-	1055	378	830

TABLE I (Cont'd)

Sample No.	Heat Treatment	Hardness (Rc)	Actual Gauge	Ballistic Limit .45[1]	G-2[2]	G-1-A[3]	G-1-S[4]
26-1	Normalized from 1650°F.	29	.050"	584	—	-	-
26-2	"	28	.048"	-	1370	430	940
27-1	Quenched from 1600°F., into salt bath at 675°F., for 10 minutes.	38	.050"	684	—	-	-
27-2	"	43	.052"	-	1195	426	940
27-3	"	33	.050"	615	—	-	-
For Comparison:							
Hadfield Manganese Steel		—	.045"	950	1675	500	1050

*The ladle carbon of this heat was 0.20 but apparently decarburization occurred during rerolling.

1. Cal. .45 steel-jacketed ball projectile - 230 grains.
2. Cal. .22 fragment-simulating projectile - 17 grains.
3. Cal. .30 fragment-simulating projectile - 150 grains.
4. Cal. .30 fragment-simulating projectile - 34 grains.