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AUTOMOTIVE DIVISION

REPORT ON

BALLISTIC EVALUATION OF ENGINE COMPARTMENT GRILLES FOR ARMORED PERSONNEL CARRIER, M113 (U)

FC

Eleventh Report on Ordnance Project TW-403

(D. A. Project No. 545-07-032)

(AD-1286)

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ABERDEEN PROVING GROUND
MARYLAND

AUTHORITY: ORDTW-CVS JCKelton/dwk

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BALLISTIC EVALUATION OF ENGINE COMPARTMENT GRILLES FOR ARMORED PERSONNEL CARRIER, M113 (U)

Eleventh Report on Ordnance Project TW-403

Dates of Test: 5 June to 10 October 1959

(C) ABSTRACT

Four designs of grilles for the armored personnel carrier, M113 were submitted ~~to Aberdeen Proving Ground~~ for tests to determine the protection that each afforded against combat attack. The four types of grilles were an all-steel grille, an all-aluminum grille, and ~~two~~ 3 combination steel and aluminum grilles. Fragment simulators ranging in size from the ~~caliber~~ .30 cal 45-grain projectile to the 20-mm, 830-grain projectile were fired at the grilles at striking velocities which correspond to the velocities expected from corresponding size fragments at a distance of 50 feet from an exploding 105-mm, HE projectile. The offensive grenade, Mark III, and the fragmentation grenade, M26 were statically detonated on the grilles. A protection rating was calculated for each grille. The all-steel grille was the only one that gave satisfactory results for all test conditions. The combination steel and aluminum grilles of the designs tested did not give satisfactory protection, but it is recommended that other designs using this combination be tested. (C)

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(The Annex is on file in the Technical Library, APG, for reference purposes. Copies of the Annex may be furnished to recipients of this report upon request.)

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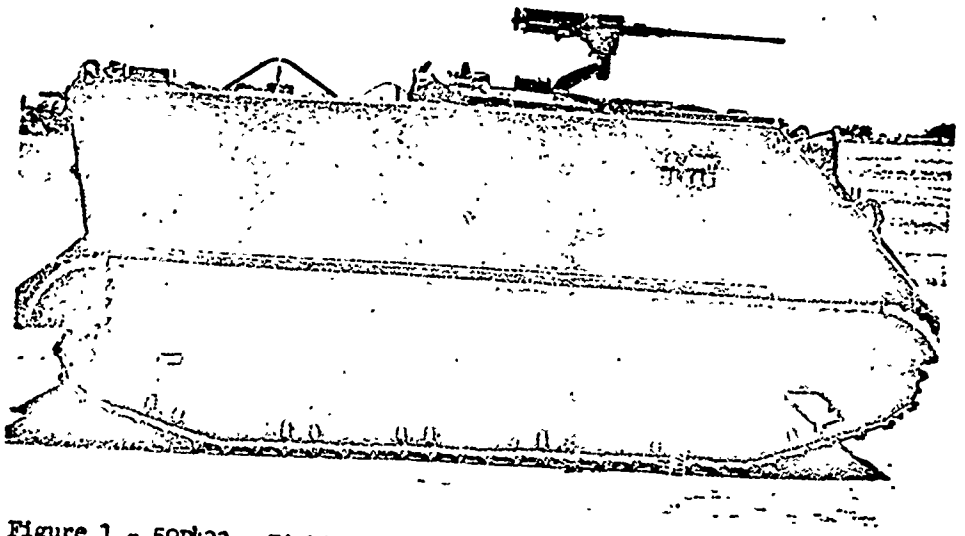

Figure 1 - 59P433: Right Side View of Armored Personnel Carrier, M113.

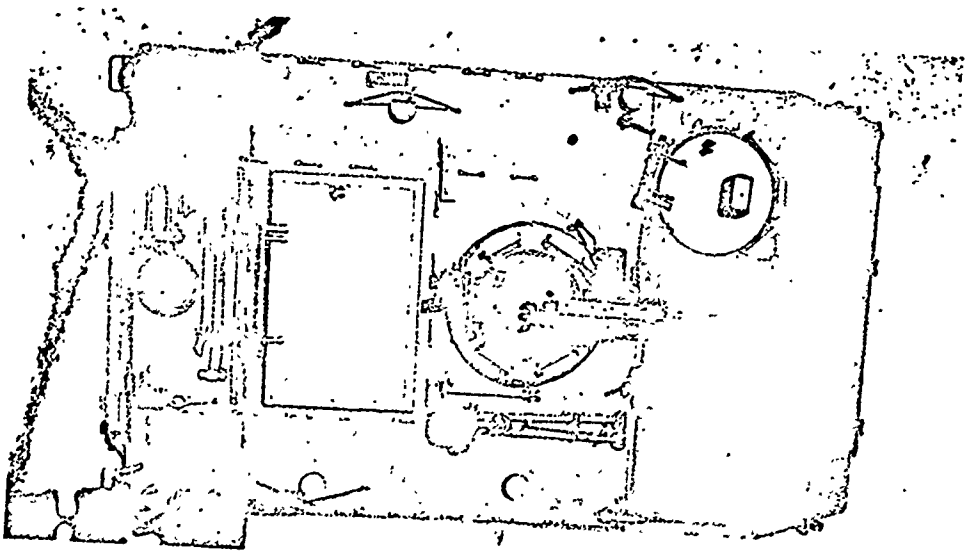

Figure 2 - 59P436: Top View of Armored Personnel Carrier, M113.

1. (U) INTRODUCTION

In the present concept of nuclear warfare, dispersion of troops and equipment is essential. To engage in battle with an enemy which possesses nuclear capabilities, high-speed, high-mobility vehicles are needed to transport personnel and equipment from their widely dispersed locations to concentrated points of attack and to redisperse quickly to hold the newly acquired terrain.

To meet these requirements CONARC requested the Ordnance Tank-Automotive Command to design a lightweight personnel carrier that would be both air-transportable and air-dropable. The vehicle was also required to provide protection against fragments from bursting high-explosive shells and against small arms projectiles.

This vehicle, designated the Carrier, Personnel, Full-Tracked, Armored, M113 was tested at Aberdeen Proving Ground to determine the protection that it afforded against ballistic attack. It was observed in this test, and reported in Armor Test Report No. AD-1271, that the engine compartment grilles had poor structural strength, as evidenced by the extreme deformation and breaking of the louvers under high-explosive shell fragment impacts. From these test results it was concluded that the grille should be redesigned to afford greater protection to the engine. To fill this requirement, four different grilles were designed and fabricated. Eight grilles of each design were submitted for ballistic evaluation. Thus the objective of the test reported herein was to determine which of these four grille designs afforded the best ballistic protection for the engine compartment of the M113 armored personnel carrier.

2. (U) DESCRIPTION OF MATERIAL

The grilles for the M113 armored personnel carrier (Figure 1) can be used interchangeably in either the intake or exhaust position (Figure 2). Each grille covers an area approximately 28 inches square and each is approximately 4 inches thick.

The all-aluminum grille, DTA48459 (Figure 3), consists of aluminum louvers that are welded to the frame of the grille. This grille weighs approximately 176 pounds.

Figure 3 - 59T3139: Side View of All-Aluminum Grille, DTA48459.

The straight steel and aluminum grille, DTA48460 (Figure 4), consists of front steel armor bars placed perpendicular to the plane of the grille and backed up by two rows of aluminum bars. This grille weighs approximately 246 pounds.

Figure 4 - 59T3138: Side View of Straight Steel and Aluminum Grille, DTA48460.

The all-steel grille, DTA48461 (Figure 5), is constructed with steel armor bars placed at a 60-degree angle to the plane of the grille and backed up by two rows of steel bars. This grille weighs approximately 360 pounds.

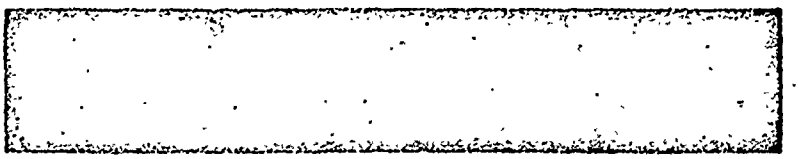

Figure 5 - 59T3139: Side View of All-Steel Grille, DTA48461.

The slant steel and aluminum grille, DTA48462 (Figure 6), is constructed the same as the all-steel grille with the exception that the back-up bars are made of aluminum. This grille weighs approximately 274 pounds.

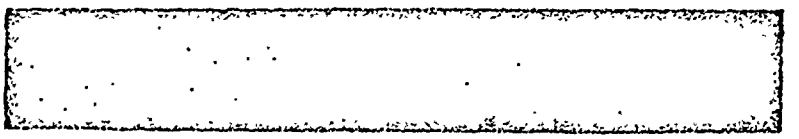

Figure 6 - 59T3138: Side View of Slant Steel and Aluminum Grille, DTA484622.

The construction of the straight steel and aluminum grille, the all-steel grille, and the slant steel and aluminum grille is similar in that the armor bars of the grille are held in place in the grille frame by rods that pass through both ends of the armor bars. This design facilitates rapid fabrication and easy replacement of damaged bars. However, the replacement of damaged bars cannot be accomplished if the grille frame structure which supports the armor bars has been damaged.

3. (C) DETAILS OF TEST

3.1 Procedure and Results

The testing program was divided into a small arms phase and a grenade phase.

3.1.1 Small Arms Firing. The grilles were fired on in three positions: normal to the grille, into the opening between the bars or louvers, and across the bars or louvers. In each of these positions fragment simulators were fired at striking velocities corresponding to the velocities expected from the same size fragments encountered at a distance of 50 feet from an exploding 105-mm, HE projectile.

The following are the striking velocity levels at which the fragment simulators were fired:

20-mm, 830-gr, FS	3000 fps
.712-in., 600-gr, FS	2975 fps
Cal .50, 200-gr, FS	2750 fps
Cal .30, 45-gr, FS	2350 fps

The 830-grain fragment simulators were also fired at a velocity of 2425 fps normal to the grille. This conforms with the military specification requirement for the roof plate which surrounds the grilles.

Caliber .30 ball ammunition was fired on the grilles which were maintained in the same three positions. This ammunition consisted of service rounds which yielded striking velocities of approximately 2800 fps.

Witness plate (Figure 7) consisting of 0.020-inch dural sheets was placed about six inches behind the grille. The size of the penetrations in this sheet was used as the basis of evaluation of the protection afforded by the grille.

Figure 7 - 59T3365: Dural Witness Plate, Showing Rounds 252, 253, 256, 257, 258, and 259.

The round-by-round results of the small arms firing are presented in Appendix B.

3.1.1.1 Analysis of Data. To analyze the results of this test from the round-by-round data without a method of data reduction would be a laborious task. Therefore, a protection rating system was used to reduce the raw data obtained to a compact yet representative form. The rating system used is explained in detail in Appendix C, page C-1 and C-2. Briefly the protection rating system takes the following factors into consideration.

a. The percentage of projectiles fired that were defeated by the grille.

b. Average amount of damage sustained by the dural witness sheets from those projectiles which were not completely defeated by the grille.

A protection rating was calculated for each grille for each test condition. A summary of these calculations is presented in Appendix D and the protection ratings from these calculations are given in Table I.

Table I. Summary of Protection Ratings

Grille	Cal .30 FS	Cal .30 Ball	Cal .50 FS	600-gr FS	20-mm FS
All Steel	100	72	82	--	82
All Aluminum	100	75	88	59	53
Slant Steel and Aluminum	93	68	67	65	57
Straight Steel and Aluminum	100	50	62	--	--

3.1.1.2 Results. From the summary of the protection ratings it may be noted that the all-steel grille and the all-aluminum grille gave comparable results for the less severe conditions, up to and including caliber .50 fragment simulators, and that this protection was good. Conversely, the combination steel and aluminum grilles afforded poor protection and were able to adequately defeat only the 45-grain, caliber .30 fragment simulator. The aluminum back-up bars of both steel-aluminum combination grilles were readily sheared or separated by any projectile that passed the frontal armor bars (Figure 8).

Although the all-aluminum grille afforded good protection at the less severe conditions, it afforded poor protection against the 600- and 830-grain fragment simulators. The aluminum louvers were damaged severely and were displaced (Figure 9). The hook or trap on the rear of the louver which worked effectively in stopping the caliber .50, 207-grain fragment simulator was not capable of stopping the larger 600- and 830-grain fragments.

The all-steel grille afforded good protection against all the projectiles used in the test, with only minor damage to the grille, (Figure 10).

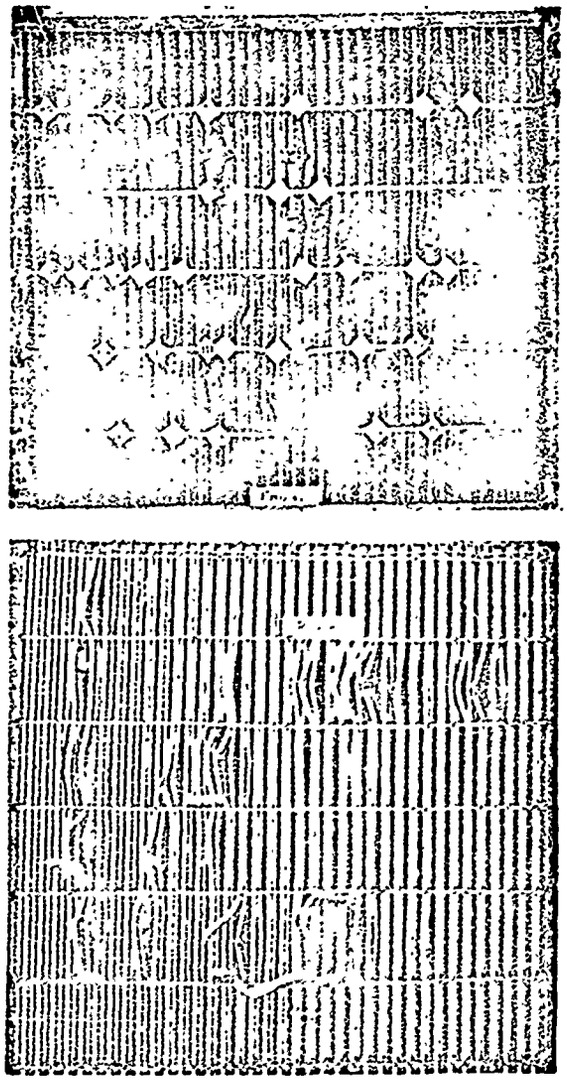

Figure 8 - 59T3157: Slant Steel and Aluminum Grille, DTA48462. Rounds 88 through 91 and Round 103 Were 20-mm, 830-Grain Fragment Simulators. Rounds 92 through 102 and 104 through 109 Were .712-Inch, 600-Grain Fragment Simulators. Rounds 110 through 118 were Caliber .30, 45-Grain Fragment Simulators. Rounds 119 and 120 were Caliber .30, Ball.

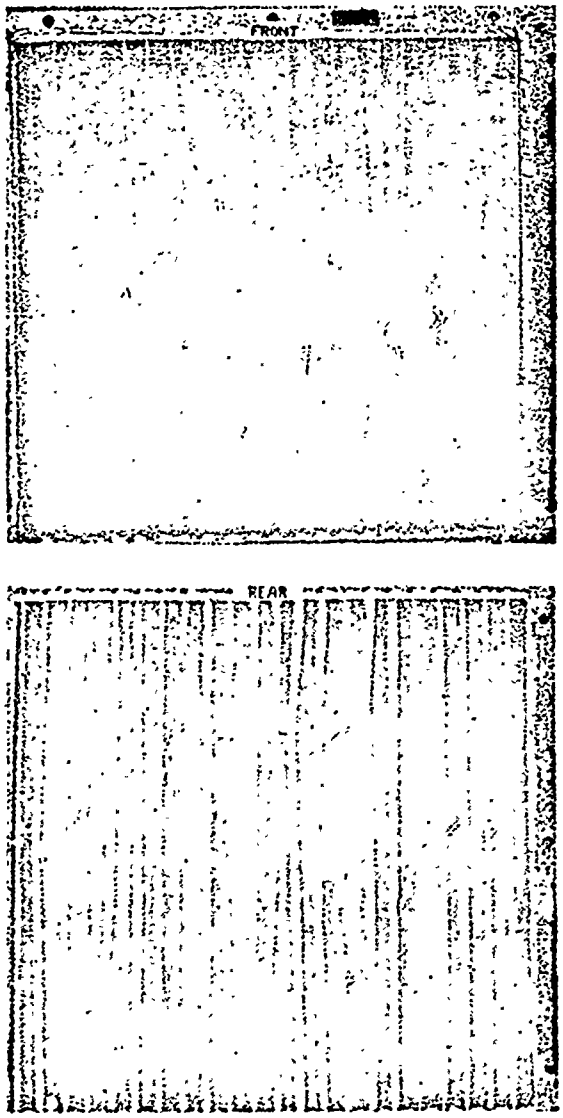

Figure 9 - 59T3159: All-Aluminum Grille, DTA48459. Rounds 63 through 65 Were .712-Inch, 600-Grain Fragment Simulators. Rounds 66 and 67 Were 400-Grain Fragment Simulators. Rounds 68 through 81 Were 20-mm, 830-Grain Fragment Simulators.

The all-steel grille afforded good protection against all the projectiles used in the tests, with only minor damage to the grille (Figure 10).

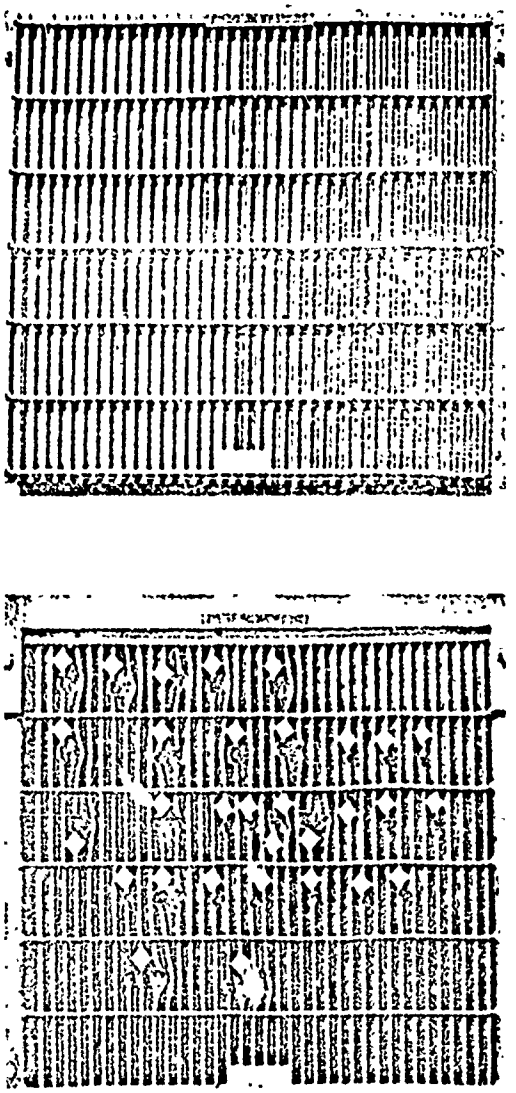

Figure 10 - 59T3364: All-Steel Grille, DTA48461. Rounds 211 through 226 Were Caliber .50, 207 Grains Fragment Simulators. Rounds 227 through 241 Were 20-mm, 830-Grain Fragment Simulators.

3.1.1.3 Observations. The all-aluminum grille afforded less protection when it was positioned so that the line of fire was directed across the louvers than it did in either the normal position (0° obliquity) or the into-the-opening-between-the-louvers position. The strongest part of the all-aluminum louver type grille is the center area of the louver bars, but when this grille is attacked in the "across" condition, the projectile passes parallel to this center area. Thus, for the smaller projectiles, up to the 600-grain fragment simulator, it is possible for the projectile to pass completely through the grille and not strike this strong area of the aluminum louver bars. The aluminum grille afforded its maximum protection when the firing was directed into the openings between louvers.

The direction of attack which was most lethal for the all-steel grille, the slant steel and aluminum grille, and the straight steel and aluminum grille, was in each case the into-the-openings-between-louvers position.

3.1.2 Grenade Static Detonation. Grenades, M26 fragmentation and Mark III offensive, were statically detonated directly on top of the grilles. The grenades were placed with their longitudinal axis either across or parallel to the bars of the grilles. Dural witness plate was placed directly below the grille for the first few detonations. In these detonations the blast demolished the dural to such an extent that detailed damage assessment was impossible; therefore, for subsequent detonations 1/2-inch plywood was placed about ten inches below the grille.

3.1.2.1 Results. The small aluminum bars of both of the combination steel-aluminum grilles were sheared off by the blast (Figures 11 and 12) with sufficient energy for the sheared portion of the bars to penetrate the plywood.

The all-aluminum grille (Figure 13) was damaged to the extent that the louvers at the point of detonation were displaced and some welds were fractured.

The all-steel grille (Figure 14) withstood the grenade detonations satisfactorily with damage only to the spacer bars.

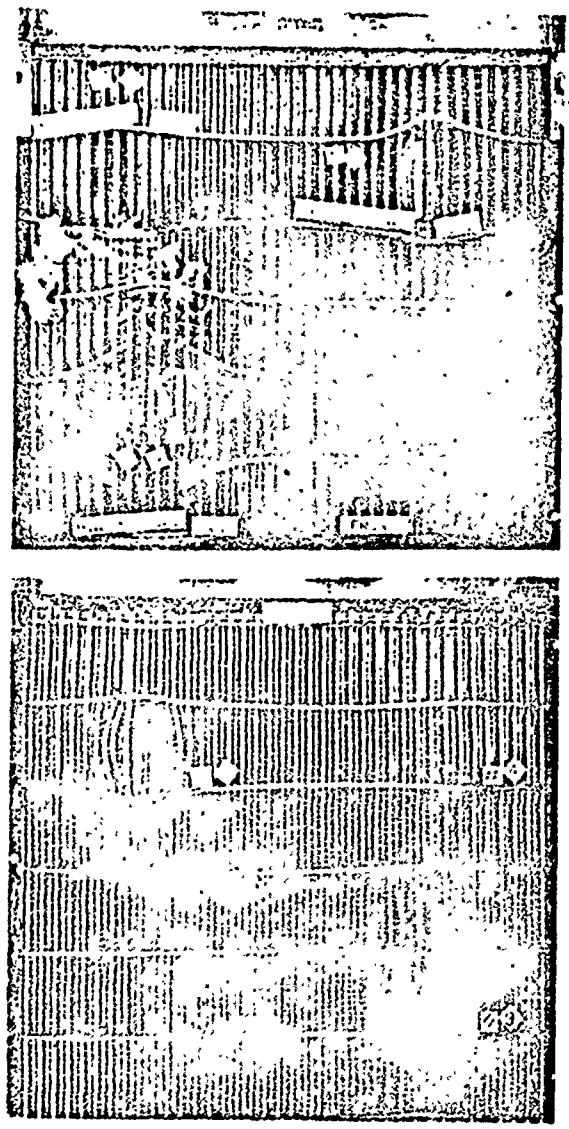

Figure 11 - 59T3152: Straight Steel and Aluminum Grille, DTA48460. Grenade No. 4, Mark III Offensive "With" the Bars. Grenade No. 7, M26 Fragmentation Grenade "Across" the Bars. Grenade No. 9, Mark III Offensive "Across" the Bars. Note Sheared Aluminum Bars on Rear.

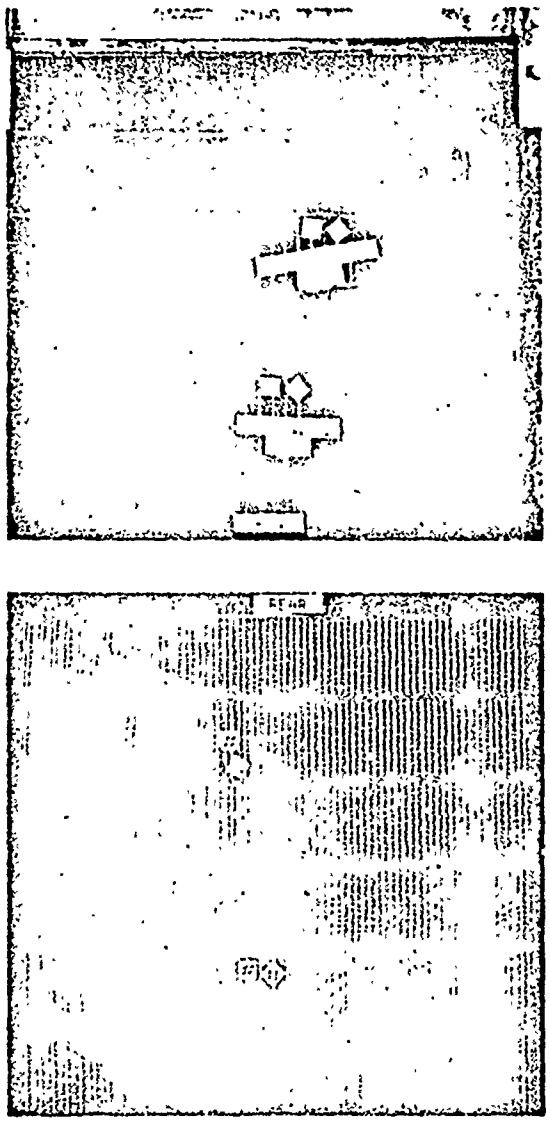

Figure 12 - 59T3154: Slant Steel and Aluminum Grille, DTA48462. Grenade No. 10, Mark III Offensive Grenade Placed Across the Bars. Grenade No. 11, M26 Fragmentation Grenade Placed Across the Bars.

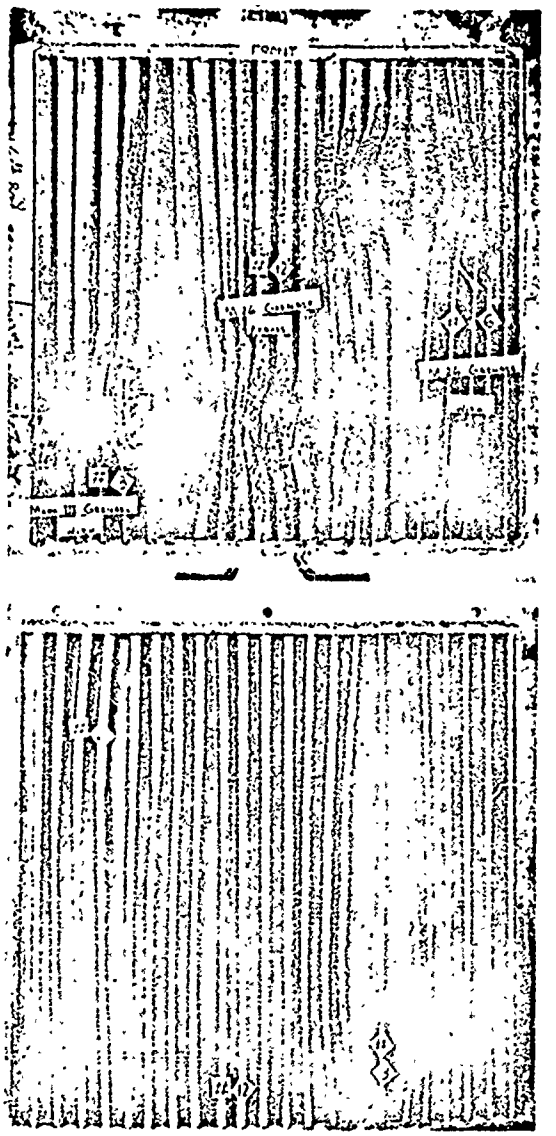

Figure 13 - 59T3153: All-Aluminum Grille, DTA48459. Grenade No. 3, Mark III Offensive, Placed "With" the Bars. Grenade No. 6, M26 Fragmentation, Placed "With" the Bars. Grenade No. 12, M26 Fragmentation, Placed Across the Bars.

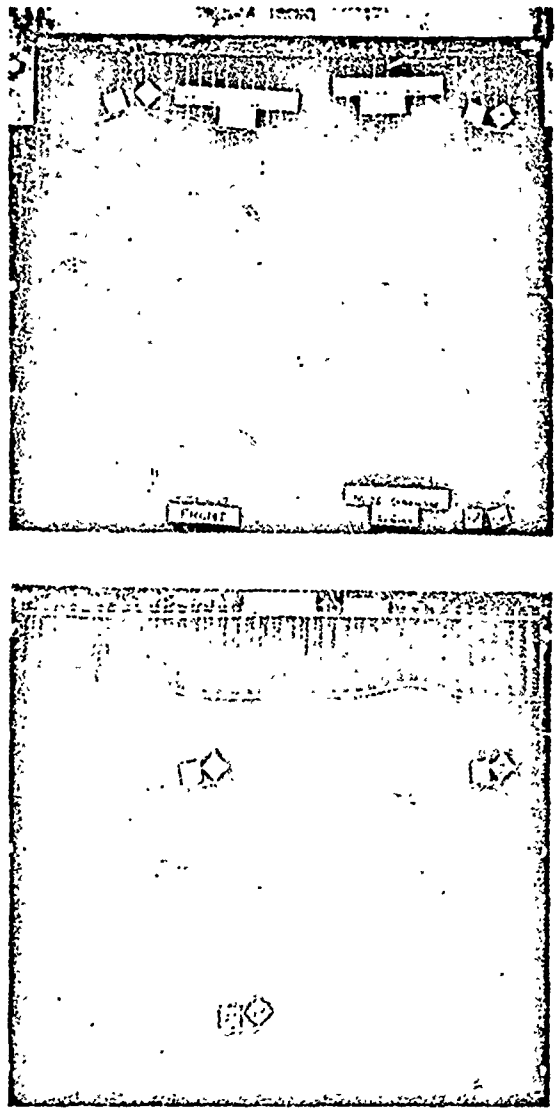

Figure 14 - 59T3155: All-Steel Grille, DTA48461. Grenade No. 5, Mark III Offensive, Placed "With" the Bars. Grenade No. 8, Mark III Offensive, Placed Across the Bars. Grenade No. 13,M26 Fragmentation, Placed Across the Bars.

4. (C) CONCLUSIONS

It is concluded that:

a. The all-steel grille is the best of the four types of grilles tested. It will afford good protection against fragments from exploding high-explosive projectiles and has sufficient structural strength to withstand grenade detonations.

b. The all-aluminum grille will afford good protection against small fragments, but will not provide satisfactory protection against larger fragments (600- to 830-grain). Grenade detonations will structurally damage this grille.

c. The straight steel and aluminum grille and the slant steel and aluminum grille will afford very poor protection against HE projectile fragments and grenades. The small aluminum back-up bars do not provide adequate strength.

5. (C) RECOMMENDATIONS

It is recommended that:

a. The all-steel grille be considered satisfactory.

b. The concept of frontal steel armor louver bars backed up by the lower-density, fragment-absorbing aluminum louver bars, be investigated further. A possible design (Figure 15) which used the best features of the all-steel grille and the all-aluminum grille should provide protection superior to the all-steel grille, with a possible weight reduction.

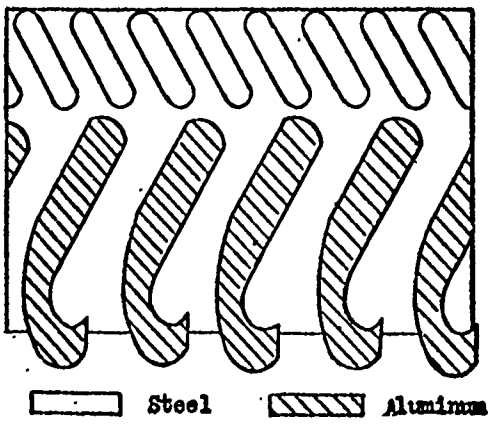

Figure 15: Sketch of Proposed Grille Design.

SUBMITTED:

J C Kelton

J. C. KELTON
Lt, Ord Corps
Project Engineer

REVIEWED:

W. C. Pless

W. C. PLESS
Chief, Armor
Branch

C. D. Montgomery

for W. A. GROSS
Chief, Automotive
Division

APPROVED:

H. A. Noble

H. A. NOBLE
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for Engineering Testing
Development and Proof Services

APPENDICES

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APPENDIX A

Correspondence

ORDTA-CVS
00/8C-11314
ORDMC-RB.1.5

1st Ind (C)

Mr Duvall/ohs/54137

SUBJECT: Test Directive for Air-Transportable Multipurpose Vehicle Family, Armored, T113E1 and T113E2, (Ordnance Project No. TW-403), Department of the Army Project No. 545-07-032 (U)

DA, ORD O, Washington 25, D. C., Sep 12 1958

TO: CG, Aberdeen Proving Ground, Maryland ATTN: ORDBG-I

1. Subject test directive, as outlined in the basic letter, is forwarded approved.

2. In view of the "crash" development program which has been established for subject vehicles, it is imperative that every expedient be used to meet the scheduled dates set forth in paragraph 2 of the basic letter.

3. Program authorization for these tests is included in the FY 59 Research and Development Program. Department of Army Priority 1A applies.

FOR THE CHIEF OF ORDNANCE:

/t&s/ M. A. KINLEY
Colonel, Ord Corps
Assistant

Copy Furnished:
CG, OTAC
ATTN: ORDMC-RB.1.5

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HEADQUARTERS
ORDNANCE TANK AUTOMOTIVE COMMAND VSGuminski/cb/35251
DETROIT ARSENAL
28251 Van Dyke Avenue
Center Line, Michigan

IN REPLY 500/otac (27 Aug 58) AUG 27 1958
REFER TO
ORDMC-RB.1.5

SUBJECT: Test Directive for Air-Transportable Multipurpose Vehicle Family, Armored, T113E1 and T113E2, (Ordnance Project No. TW-403), Department of the Army Project No. 545-07-032 (U)

TO: Chief of Ordnance
Department of the Army
Washington 25, D. C.
ATTENTION: ORDTW-CVS, Mr. N. T. Duvall

1. The purpose of this Directive is to establish the procedure to be followed in testing the subject vehicles. Due to the "Crash" nature of this development program, it is in the interest of expedience that Ordnance engineering tests on the T113E1 vehicle and the T113E2 vehicle be conducted concurrently at two test sites. It is therefore recommended that the CARRIER, PERSONNEL, FULL-TRACKED, Armored, T113E2 be evaluated at the Ordnance Test Activity, Yuma, Arizona, and the CARRIER, PERSONNEL, FULL-TRACKED, Armored, T113E2 be evaluated at Aberdeen Proving Ground, Maryland.

2. It should be noted that the following time schedule has been firmly established for the program in order that early production of a T113 type Personnel Carrier can be attained:

a. 15 January 1959 - CONARC evaluation of T113E1 and T113E2 vehicles completed to the extent that a decision can be rendered on the selection of a preferred type, T113E1 or T113E2 vehicle, to be produced.

b. 1 February 1959 - Type Classification to be made on the vehicle finally selected.

c. 1 April 1959 - Issuance of a Production Contract.

An extremely high priority must therefore be established at Yuma, APG, and Fort Churchill for this test program, so as to complete all test phases by 1 March 1959.

3. Material: The following is tentative schedule for the delivery of pilots and ballistic hulls to the Yuma Test Station and Aberdeen Proving Ground during Fiscal Year 1959.

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ORDMC-RB.1.5 Aug 28 1958

SUBJECT: Test Directive for Air-Transportable Multipurpose Vehicle Family, Armored, T113E1 and T113E2, (Ordnance Project No. TW-402), Department of the Army Project No. 545-07-032 (U)

a. CARRIER, PERSONNEL, FULL-TRACKED: Armored T113E1:

TYPE	DESTINATION	APPROXIMATE ARRIVAL DATE
Pilot No. 1	Yuma Test Station Yuma, Arizona	27 Aug 1958

c. CARRIER PERSONNEL, FULL-TRACKED: Armored T113E2:

TYPE	DESTINATION	APPROXIMATE ARRIVAL DATE
Pilot No. 2	Aberdeen Proving Ground, Maryland	1 Sept 1958

c. BALLISTIC HULLS:

TYPE	DESTINATION	APPROXIMATE ARRIVAL DATE
T113E1 and T113E2	Aberdeen Proving Ground, Maryland	1 Oct 1958

4. Scope of Tests:

a. The tests required include the complete evaluation and determination of vehicular performance characteristics, as established for the subject type vehicles by OTCM 36049 dated 5 January 1956 with the exception that where therein is stated the requirement that the vehicle "....shall not exceed 16,000 pounds combat loaded less personnel", the requirement for the T113E1 vehicle shall be that its air-drop weight does not exceed 17,500 pounds, and the requirement for the T113E2 vehicle shall be that its combat loaded weight does not exceed 24,000 pounds. Air-drop weight of the vehicle, defined as it applies to the T113E1 vehicle, is its combat loaded weight less the following items: Personnel, Track Pads, 80% Fuel, Ammunition, and Winterization Kit.

b. All tests are to be conducted in accordance with items listed in the Ordnance Proof Manual, Vol. II, Automotive testing under OPM 60-05, dated 1 October 1957. Tests not covered by the OATP will be prescribed by special instructions in this directive or in supplements thereto.

ORDMC-RB.1.5 Aug 27 1958

SUBJECT: Test Directive for Air-Transportable Multipurpose Vehicle Family, Armored, T113E1 and T113E2, (Ordnance Project No. T7-403), Department of the Army Project No. 545-07-032 (U)

5. Photography - In addition to the normal requirement for still photographs depicting general views of the vehicle, and those which clarify and supplement component deficiency reports, it is requested that documentary motion pictures also be submitted with the final test report covering each major phase of the test program.

6. Tests to be performed on the T113E1 pilot, destined for evaluation at Yuma Test Activity with the relative order of priority, are as follows:

a. OPM 60-25: Mechanical Inspection

*b. OPM 60-30: Preliminary Operation

c. OPM 60-95: Cooling - During this phase of the test, the T113E1 vehicle shall be loaded to a gross weight of 24,000 pounds.

*d. OPM 60-85: Mobility - During this phase of the tests, the T113E1 vehicle shall be evaluated during desert type operation - sand dunes...etc., at both a gross vehicle weight of 21,000 lbs. and 24,000 lbs.

e. OPM 60-300: Environmental Factors. Special emphasis should be placed on the adequacy of the vehicle ventilating system while operating with a complete crew complement.

f. OPM 60-170: Tracks and Suspension.

g. OPM 60-60: Load Distribution and Ground Pressure.

*h. OPM 60-72: Drawbar Pull.

*i. OPM 60-74: Acceleration, Maximum - Minimum Speeds.

*j. OPM 60-40: Vehicle Fuel Consumption Tests.

*k. OPM 60-80: Gradeability and Side Slope Performance.

l. OPM 60-71: Braking.

m. OPM 60-50: Standard Obstacles.

*n. OPM 60-75: Steering.

*o. OPM 60-90: Fording (Note Amphibious Characteristics).

p. OPM 60-65: Determination of Center of Gravity and Moments of Inertia about a Longitudinal and Traverse Axis.

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q. OPM 60-230: Secondary Armament.

r. OPM 60-15: Characteristics.

s. OPM 60-20: Deficiency Reports.

NOTE: Those OPM features denoted by an asterisk (*) are to be performed concurrently with the T113 Personnel Carrier presently at the Yuma Test Station, however equipped with the new 15-inch track as utilized on the T113E1 vehicle, and a new Ordnance Power Package, AOSI-314 Engine and XTG-90 Transmission.

7. All tests at Yuma shall be completed in sufficient time to permit preparation and shipment of the T113E1 vehicle to Fort Churchill, for cold weather environmental tests, during the 1958-59 winter test program. All Yuma tests must be completed by 31 December 1958. Air shipment of the T113E1 vehicle is contemplated from the Yuma Test Station to Fort Churchill. Tests at Fort Churchill are to begin no later than 15 January 1959.

8. The following tests applicable to Arctic conditions and such others as may be determined by the test engineer or the Ordnance Tank-Automotive Command by supplements to this Directive, are to be conducted on the vehicle at Fort Churchill.

a. OPM 60-300: Environmental Factors.

b. OPM 60-301: Field Cold Starting and Warm-Up.

c. OPM 60-302: Field Test of Personnel Heating Systems.

d. OPM 60-85: Mobility - Observations are to be made during operation on the frozen lake and frozen muskeg test courses, during trials on untravelled drift snow of varying depths, on level ground, and prepared ten and twenty per cent slopes. The T113E1 vehicle shall be evaluated during this phase at both a gross vehicle weight of 21,000 pounds and 24,000 pounds.

e. OPM 60-72: Drawbar Pull. The capacity of the vehicle to tow sleds, wanigans, and other appropriate trailed loads under various mobility conditions, is to be determined at the two gross vehicle weights specified above.

9. Tests to be performed at Aberdeen Proving Ground on the CARRIER, PERSONNEL, FULL-TRACKED: Armored T113E2 are as follows:

a. OPM 60-25: Mechanical Inspection.

b. OPM 60-30: Preliminary Operation.

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c. OPM 60-85: Mobility

d. OPM 60-170: Tracks and Suspension - Initial tests on the vehicle are to be conducted with 24-inch diameter roadwheels, 10-tooth sprockets, 17-inch diameter fixed track return idlers, and solid track blocks. Tests on the vehicle are also to be so [illegible] using 22-inch diameter roadwheels, 9-tooth sprockets, 15-inch diameter [illegible]ed return idlers, and skeletonized blocks. A comparative evaluation report between the two systems is to be submitted.

e. OPM 60-60: Load Distribution and Ground Pressure.

f. OPM 60-72: Drawbar Pull.

g. OPM 60-74: Acceleration, Maximum-Minimum Speeds.

h. OPM 60-40: Vehicle Fuel Consumption Tests.

i. OPM 60-80: Gradeability and Side Slope Performance.

j. OPM 60-71: Braking.

k. OPM 60-50: Standard Obstacles.

l. OPM 60-117: Churchville Final Drive Tests.

m. OPM 60-75: Steering.

n. OPM 60-90: Fording.

o. OPM 60-65: Determination of Center of Gravity and Moments of Inertia about Longitudinal and transverse axis.

p. OPM 60-230: Secondary Armament.

q. OPM 60-70: Torque Measurements for Tracklayers.

r. OPM 60-110: Stowage.

s. OPM 60-175: Radio Interference Tests.

t. OPM 60-305: Human Engineering.

u. OPM 60-115: Endurance Testing of Combat Vehicles (4,000 miles - See OTCM 36049).

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v. OPM 60-15: Characteristics.

w. OPM 60-20: Deficiency Reports.

10. Tests on the BALLISTIC HULLS are to be performed at Aberdeen Proving Ground generally in accordance with OPM 22-11, "Armor Plate Testing", and OPM 25-28, "Tests of Vulnerability", however, specificaally under the following guidance:

a. OBJECTIVE: Vulnerability test of the hull of the CARRIER, PERSONNEL, FULL-TRACKED, Air Borne, T113E1 and T113E2.

b. DESCRIPTION: Two (2) hulls, one T113E1 and one T113E2, will be supplied. In addition, nine (9) grilles, three (3) of three (3) different designs, will be submitted for evaluation. The hulls will be fabricated from weldable aluminum armor and the grilles from steel and/or aluminum armor.

c. PROCEDURE: In order to ascertain the level of protection afforded the two (2) hulls (with different thicknesses), the following tests shall be conducted:

(1) Phase I - Fragmentation Tests: The sides and roof of the hulls are to be impacted by fragments from 105 mm HE shell at 90 and 50 feet.

(2) Phase II - Blast Evaluation of Ambient Temperature: The weldment joints are to be ballistically shock tested using the 37 mm shell, HE, M54, 40 mm HE-TNT shell and/or 57 mm proof projectile M1001. The selection of the type of round for testing each weld joint to be determined by APG personnel.

(3) Phase III - Resistance to Penetration of the Hull Armor with Small Arms: The ballistic limits shall be determined in accordance with the condition enumerated in the table below:

			T113E1		T113E2	
Area	Projectile	Obliquity	(Inches) Thickness	Approx. B-L	(Inches) Thickness	Approx. B-L
Front-Upper Glacis	.30 Cal AP	45°	1-1/2	Inv.*	1-1/2	Inv.*
Front-Lower Glacis	.30 Cal AP	30°	1-1/4	2355	1-1/2	2600
Front-Upper Glacis	.50 Cal AP	45°	1-1/2	2390	1-1/2	2390
FrontLower Glacis	.50 Cal AP	30°	1-1/4	1675	1-1/2	1900
Side-Upper	.30 Cal AP	0°	1-3/4	2540	1-3/4	2540
Sider-Lower	.30 Cal AP	0°	3/4	1510	1-1/4	2055
Side-Lower	.30 Cal Ball	0°	3/4	2200	1-1/4	2885
Rear	.30 Cal Ball	0°	1-1/4	2885	1-3/4	----
Rear	.30 Cal AP	0°	1-1/4	2055	1-3/4	2540
Roof	20MM AP	60°	1-1/2	2200	1-1/2	2200
Roof	20MM AP	65°	1-1/2	2600	1-1/2	2600

* Request verification that round will not penetrate the armor.

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(4) Phase IV - Grilles: It is desired that a ballistic evaluation of the different types of grilles be conducted. It is suggested that the grilles be tested under the following conditions:

Projectile	Direction of Firing	Obliquity (Degrees)
.30 Cal Fragment Simulator	Across Segments of Grille	0
.30 Cal Fragment Simulator	Into Segments of Grille	0
.50 Cal Fragment Simulator	Across Segments of Grille	0
.50 Cal Fragment Simulator	Into Segments of Grille	0
20MM Fragment Simulator	Into Segments of Grille	30 & 45
20MM Fragment Simulator	Across Segments of Grille	30 & 45
.30 Cal Ball	Into Segments of Grille	0
.30 Cal Ball	Across Segments of Grille	0
.50 Cal Ball	Into Segments of Grille	45 & 60
.50 Cal Ball	Across Segments of Grille	45 & 60
.50 Cal AP	Into Segments of Grille	60 & 75
.50 Cal AP	Into Segments of Grille	60 & 75
20MM AP	Into Segments of Grille	60 & 75
20mm AP	Across Segments of Grille	60 & 75
Fragmentation Grenade		
Offensive Grenade		

(5) Phase V - Splash Testing: Bullet splash from .30 Caliber ball and AP rounds and grenades, shall be directed towards various openings of the vehicles, such as door...etc., to determine splash susceptibility or keying of movable parts.

d. REPORTS: A final report will be required. Distribution will be in accordance with distribution list, which will be forwarded under separate cover at a later date.

11. It is requested that weekly reports of test be forwarded to Ordnance Tank-Automotive Command, Research and Development Division, Detroit Arsenal, Center Line, Michigan, ATTENTION: ORDMC-RV.1.5, and copies be sent directly to: Food Machinery and Chemical Corporation, San Jose, California, ATTENTION: Mr. G. Tedrow.

12. It is further requested that this Command be continually advised of the testing schedule so that representatives from this Command, and Food Machinery and Chemical Corporation may be at the test facility to observe critical portions of the testing.

FOR THE COMMANDER:

/t&s/ S. H. FULLER
Chief Development Engineer
Research & Development Division

Copies furnished:
Mr. Montgomery, APG, Aberdeen, Md.
Mr. Snider, Yuma Test Sta., Yuma, Ariz.

APPENDIX B

Small Arms Firing, Round-by-Round Data

SMALL ARMS FIRING

ROUND-BY-ROUND DATA

All Aluminum Grille
DTA 48459

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
		Caliber .30 Fragment Simulator 45 Grain		
170	2491	0°	PP(P)	
171	1940	0°	PP(P)	
172	2399	0°	PP(P)	
173	2436	35° into	PP(P)	
174	2514	35° into	PP(P)	
175	2442	35° into	PP(P)	
184	2384	35° across	PP(P)	
185	2300	35° across	PP(P)	
186	2003	35° across	PP(P)	
187	2446	35° across	PP(P)	
		Caliber .30 Ball		
166	2800	0°	CP(P)	1 hole: 1/4" x 1/4"
167	2828	0°	PP(P)	
168	2796	0°	CP(P)	26 holes: 2"x1-1/4", 3(1/2"x1/2"), 7(1/4"x1/4"), 3(1/8"x1/8") 12 pin
169	2818	0°	PP(P)	
176	2805	35° into	PP(P)	
177	2814	35° into	PP(P)	
178	2805	35° into	PP(P)	
179	2866	35° into	PP(P)	
180	2819	35° across	CP(P)	1 hole: 1/4"x1/32"
181	2833	35° across	CP(P)	23 holes: 1-1/2"x1", 3/4"x1/2", 2(5/8"x1/2"), 2(1/4"x1/4"), 5(1/8"x1/8"), 12 pin
182	2866	35° across	CP(P)	13 holes: 1-1/2"x1-1/4", 3(1/4"x1/4"), 3(1/8"x1/8"), 6 pin
183	2842	35° across	CP(P)	6 holes: 3(1/8"x1/8"), 3(1/16"x1/16")
		Caliber .50 Fragment Simulator 207 Grain		
1	2531	0°	PP(P)	
2	2758	0°	PP(P)	
198	2791	0°	PP(P)	
199	2824	0°	PP(P)	
200	2758	0°	PP(P)	
201	Lost	0°	CP(P)	1 hole: 1/2"x1/4"

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
202	2749	0°	PP(P)	
203	2853	0°	PP(P)	
3	2726	35° into	PP(P)	
4	2747	35° into	PP(P)	
5	2707	35° into	PP(P)	
6	2700	35° into	PP(P)	
7	2808	35° into	PP(P)	
8	2773	35° into	PP(P)	
195	2728	35° into	PP(P)	
196	2820	35° into	PP(P)	
197	2820	35° into	PP(P)	
9	2803	35° across	PP(P)	
10	2839	35° across	PP(P)	
188	2808	35° across	PP(P)	
189	2808	35° across	CP(P)	4 holes: 5/8"x1/2", 3/8"x1/4", 1/4"x1/4", 3/8"x1/8",
190	2638	35° across	CP(P)	3 holes: 1/2"x1/2", 2(3/4"x1/2")
191	2760	35° across	PP(P)	
192	2821	35° across	CP(P)	9 holes: 3/4"x1", 3(1/2"x1/2"), 1/2"x1/8"), 4(1/4"x1/4")
193	2812	35° across	PP(P)	
194	2793	35° across	CP(P)	2 holes: 5/8"x1/2", 1/8"x1/8")
201	2768	35° across	PP(P)	
202	2740	35° across	CP(P)	1 hole: 3/4"x3/8"
206	2771	35° across	PP(P)	
207	2758	35° across	CP(P)	1 hole: 1/2"x1/2"
208	Lost	35° across	CP(P)	1 hole: 5/8"x3/4"
209	2768	35° across	PP(P)	
210	2753	35° across	PP(P)	
		.622 In. Fragment Simulator		400 Grain
66	2138	35° across	CP(P)	Disregard - low velocity
67	2630	35° across	PP(P)	Disregard - low velocity
		.712 In. Fragment Simulator		600 Grain
53	2457	0°	PP(P)	Disregard - low velocity
54	2823	0°	PP(P)	Disregard - low velocity
55	2692	0°	PP(P)	Disregard - low velocity
56	2578	0°	PP(P)	Disregard - low velocity
57	2552	0°	PP(P)	Disregard - low velocity
58	2905	0°	CP(P)	6 holes: 4"x2", 3/8"x3/4", 2(1/4"x1/32"), 2 pin
59	3089	0°	CP(P)	3 holes: 1-1/2"x3/4", 1/2"x1/4", 1"x3/8"
60	2981	0°	CP(P)	14 holes: 2"x1", 1"x1/2", 3/4"x1/2", 1"x1/4", 2(1/2"x1/2"), 5/16"x5/16", 4(1/8"x1/8") 1/8"x1/8", 1/16"x1/16", 1 pin

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
61	3119	35° into	PP(P)	
62	2960	35° into	PP(P)	
51	3059	35° across	PP(P)	
52	Lost	35° across	PP(P)	
63	3016	35° across	CP(P)	13 holes: 3"x2-1/2", 1"x1/2", 3(1/2"x1/2"), 2(3/8"x3/8") 1"x3/4", 3/8"x1/4", 2(1/4"x1/4"), 2(1/8"x1/8")
64	3023	35° across	CP(P)	3 holes: 3/4"x1/2", 1/8"x1/8", 1/2"x1/32"
65	2988	35° across	CP(P)	12 holes: 4"x3", 1-1/2"x1-1/2", 3(1/2"x1/4"), 4(1/4"x1/4"), 1/4"x1/8", 1/4"x3/8", 1/8"x1/8"
		20-mm Fragment	Simulater	830 Grain
48	3083	0°	CP(F)	1 hole: 4-1/2"x4-1/2"
49	Lost	0°	-	Disregard
50	3067	0°	CP(P)	4 holes: 4"x1-1/2", 3/8"x3/8", 3/4"x1/4" 1/4"x 1/16"
242	2414	0°	CP(P)	2 holes: 5/8"x1/2", 3/8"x1/16"
243	2387	0°	CP(P)	2 holes: 2(1/4"x1/4")
244	2433	0°	CP(P)	1 hole: 1"x1"
245	2469	0°	CP(P)	2 holes: 1"x1/4", 1/4"x1/4"
246	2484	0°	CP(P)	2 holes: 3"x1-1/4", 5/8"x1/2"
247	2488	0°	PP(P)	
248	2455	0°	CP(P)	1 hole: 1/8"x1/8"
46	3063	35° into	CP(P)	1 hole: 3/8"x1/4"
47	3072	35° into	PP(P)	
254	3020	35° into	PP(P)	
255	3025	35° into	PP(P)	
256	3050	35° into	CP(P)	2 holes: 3-1/2"x1-3/4", 5/8"x1/2"
257	3031	35° into	CP(P)	2 holes: 1/4"x1/4", 1/8"x1/8"
258	3014	35° into	CP(P)	6 holes: 1-1/2"x1-1/4", 1"x1", 5/8"x1/4", 3/8"x3/8", 1/4"x1/4", 1/8"x1/8"
259	3002	35° into	CP(P)	4 holes: 1"x1", 3/4"x1/4", 1/2"x1/2" 5/8"x5/8"
68	3105	35° across	CP(P)	6 holes: 5"x6", 1/4"x1/4", 3/8"x3/8", 1-1/4"x3/4", 1/8"x1/8", 1/4"x1/4"
69	1769	35° across	PP(P)	Disregard

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
70	1769	35° across	CP(P)	12 holes: enlarged previous hole to 7"x6", 4(1/2"x1/2"), 4(1/4"x1/4"), 1/2"x1/4", 2(1/8"x1/4")
71	1600	35° across	CP(P)	5 holes: 2-1/2"x1-1/2", 1/4"x1/4", 3/4"x3/4", 1/8"x1/8" Disregard
72	3151	35° across	CP(P)	5 holes: 3"x1", 1/4"x1/4", 2(1/8"x1/8") 1/16"x1/16"
73	3128	35° across	CP(P)	1 hole: 1-1/2"x1-3/4" Disregard
74	3128	35° across	CP(P)	6 holes: 2-1/2"x2-1/2", 2"x1-1/2", 1-1/2"x1/2", 3(1/8"x1/8") Disregard
75	1731	35° across	CP(P)	10 holes: 5"x2-1/2", 1/2"x3/8", 5/8"x1/4", 3/8"x3/8", 2(1/4"x1/4"), 1/4"x1/8", 1/2"x1/2", 1/4"x1/16", 1/16"x1/16" - Disregard
76	1774	35° across	CP(P)	7 holes: 1"x3/8", 1-1/4"x3/4", 2"x1-3/4", 3/8"x1/4", 2(1/4"x1/4"), 3/8"x1/4", 1/2"x1/16", - Disregard
77	3129	35° across	CP(P)	1 hole: 1-1/2"x1-1/4" - Disregard
78	3106	35° across	CP(P)	8 holes: 3"x2", 2-1/2"x1", 3/4"x3/4", 3/4"x5/8", 5/8"x5/8", 3/4"x5/8", 1/2"x1/2", 1/4"x1/4"
79	3054	35° across	CP(P)	1 hole: 1-1/4"x1/2"
80	Lost	35° across	CP(P)	14 holes: 3"x1-1/2", 1"x3/4", 5/8"x1/2", 4(1/2"x1/4"), 3/8"x3/8", 2(1/4"x1/4"), 1/2"x1/8", 3/8"x1/4", 1/16"x1/16" pin
81	Lost	35° across	CP(P)	2 holes: 3"x1-1/4", 1-1/2"x3/4"
82	3028	35° across	-	Disregard
83	3074	35° across	CP(P)	4 holes: 2"x1-1/2", 1-1/4"x5/8", 1/2"x1/8", 1/2"x1/4"

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
84	3048	35° across	CP(P)	1 hole: 5" x 2-1/2"
249	2440	35° across	CP(P)	4 holes: 1-1/2"x5/8", 1-1/4"x1", 5/8"x1/4", 1/8"x1/8",
250	3031	35° across	CP(P)	6 holes: 2"x1-1/2", 2(1/2"x1/2"), 3/4"x3/8", 1/4"x1/4", 1/8"x1/8"
251	Lost	35° across	PP(P)	
252	Lost	35° across	CP(P)	2 holes: 3/4"x1/2", 1/4"x1/4"
253	2996	35° across	CP(P)	1 hole: 1/4"x1/4"

SMALL ARMS FIRING

ROUND-BY-ROUND DATA

Straight Steel and Aluminum Grille
DTA 48460

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
		Caliber .30 Fragment Simulator 45 Grain		
141	2473	0°	PP(P)	Hit bar
142	2283	0°	PP(P)	Hit bar
143	2523	0°	PP(P)	Hit bar
144	2440	0°	PP(P)	Good hit
145	2450	30° across	PP(P)	Good hit
146	2418	30° across	PP(P)	Good hit
147	2381	30° across	PP(P)	Good hit
		Caliber .30 Ball		
138	2833	0°	CP(P)	6 holes: 5/8"x1/2", 1/4"x1/16", 1/4"x1/8", 3 pin
139	Lost	0°	CP(P)	22 holes: 3/4"x3/4", 3/4"x1/4", 5/8"x3/8", 5(1/4"x1/4"), 14(1/8"x1/8")
140	2835	0°	CP(P)	20 holes: 1-1/2"x3/4", 5/8"x3/8", 7(1/4"x1/4"), 6(1/8"x1/8") 5 pin
148	2837	30° across	CP(P)	12 holes: 3/4"x1/2", 5(1/8"x1/8") 2(1/4"x1/4"), 4 pin
149	2828	30° across	CP(P)	8 holes: 1/4"x1/4", 2(1/8"x1/8"), 5 pin
150	2755	30° across	CP(P)	73 holes: 1"x5/8" 3/4"x1/2", 3(5/8"x1/2"), 12(1/4"x1/4"), 11(1/8"x1/8"), 45 pin
		Caliber .50 Fragment Simulator 207 Grain		
11	2797	0°	PP(P)	
12	2818	0°	PP(P)	
13	2825	0°	CP(P)	3 holes: 1/2"x1/4", 3/16"x1/4", 1/16"x1/16"
14	2743	0°	CP(P)	2 holes: 1/4"x1/4", 1/4"x1/16"
15	2797	0°	CP(P)	5 holes: 1/32"x1/32", 1/16"x1/16", 1/8"x1/8", 2-1/2"x1-1/4", pin

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
16	2811	0°	PP(P)	
17	2790	0°	CP(P)	3 holes: 2-1/2"x1-1/2", 1/2"x1/2", 1/4"x1/16"
18	2756	30° across	CP(P)	1 hole: 1-1/2"x1"
19	2776	30° across	PP(P)	

SMALL ARMS FIRING

ROUND-BY-ROUND DATA

All Steel Grille
DTA 48461

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
		Caliber .30 Fragment Simulator 45 Grain		
154	2483	0°	PP(P)	
155	2428	0°	PP(P)	
156	2487	0°	PP(P)	
157	2424	0°	PP(P)	
158	2522	0°	PP(P)	
159	2457	0°	PP(P)	Good hit
160	2371	30° into	PP(P)	Hit bar
161	2449	30° into	PP(P)	Good hit
162	2529	30° into	PP(P)	Good hit
		Caliber .30 Ball		
151	2814	0°	PP(P)	Good hit
152	2796	0°	PP(P)	Good hit
153	2809	0°	CP(P)	43 holes: 1"x3/4", 3(5/8"x1/2"), 5(1/4"x1/4"), 8(1/8"x1/8"), 26 pin
163	2818	30° into	CP(P)	38 holes: 5/8"x 3/8"), 5/8"x1/2", 3/4"x1/2", 3(1/4"x1/4"), 10(1/16"x1/16"), 22 pin
164	Lost	30° into	CP(P)	72 holes: 3-1/2"x1-1/2", 1"x3/4", 2(1/2"x1/2"), 10(1/8"x1/8"), 5/8"x5/8", 6(1/4"x1/4"), 51 pin
165	2800	30° into	CP(P)	37 holes: 3/4"x5/8", 3/4"x[illegible], 2(1/2"x1/2"), 2([illegible]"x1/4"), 9(1/8"x1/8"), 22 pin
		Caliber .50 Fragment Simulator 207 Grain		
33	2831	0°	CP(P)	2 holes: 5/8"x1/4", pin
34	2768	0°	PP(P)	
35	2782	0°	CP(P)	2 holes: 1/4"x1/8", 1/8"x1/8"
36	2768	0°	PP(P)	
37	2775	0°	PP(P)	
211	2744	0°	PP(P)	
212	Lost	0°	PP(P)	
213	2776	0°	PP(P)	

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
214	2800	0°	PP(P)	
30	2782	30° into	CP(P)	1 hole : 1/2"x1/8"
31	2782	30° into	CP(P)	3 holes: 1/32"x1/16", 1/32"x1/32" pin
32	2803	30° into	CP(P)	3 holes : 5/8"x1/4", 3/8"x1/8", pin
215	2783	30° into	PP(P)	
216	2769	30° into	CP(P)	6 holes: 3/8"x3/8", 3(1/8"x1/8"), 2(1/4"x1/4"),
217	2816	30° into	CP(P)	2 holes : 5/8"x5/8", 1/8"x1/8"
218	2793	30° into	CP(P)	2 holes: 3/4"x3/4", 1/4"x1/4"
219	Lost	30° into	CP(P)	2 holes: 3/8"x1/4", 1/16"x1/16"
220	2736	30° into	PP(P)	
221	2783	30° into	CP(P)	2 holes: 5/8"x1/4", 1/4"x1/16"
222	2746	30° into	CP(P)	4 holes: 5/8"x1/8", 3(1/8"x1/8")
223	Lost	30° into	PP(P)	Disregard
224	Lost	30° into	CP(P)	1 hole : 1-1/2"x3/4"
225	2768	30° into	CP(P)	6 holes: 2(1/2"x1/4"), 1/4"x1/4", 3(1/8"x1/8")
226	2768	30° into	CP(P)	4 holes: 3(1/4"x1/4"), 1/16"x1/16"
		20-mm Fragment Simulator		830 Grains
38	2894	0°	CP(P)	6 holes: 1/4"x1/4", 3/4"x1/16", 1/8"x1/16", 1/8"x1/32", 2 pin
39	2872	0°	CP(P)	2 holes: 1/4"x1/8", 1/4"x1/32"
40	2836	0°	CP(P)	3 holes: 1/4"x1/4", 1/4"x1/8", 1/2"x1/32"
41	Lost	0°	-	Disregard
42	3047	0°	CP(P)	8 holes: 1/4"x1/4", 3/8"x1/8", 1/4"x1/16", 1/8"x1/16", 2(1/16"x1/16") 2 pin
233	2452	0°	CP(P)	2 holes: 5/8"x1/8", 1/16"x1/16"
234	2425	0°	PP(P)	
235	2429	0°	PP(P)	
236	2460	0°	CP(P)	2 holes: 1/4"x1/4", 1/8"x1/8"
237	Lost	0°	PP(P)	
238	2417	0°	PP(P)	
239	2449	0°	PP(P)	
85	3063	30° into	CP(P)	25 holes: 5/8"x3/8", 1/2"x1/8", 3(1/8"x1/8"), 5(1/16"x1/16") 15 pin

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
86	3043	30° into	CP(P)	4 holes : 5/8"x1/4", 3/8"x3/8", 1/4"x1/8", 1/8" x 1/8"
87	3023	30° into	CP[illegible]	3 holes: 3/8"x1/4", 1/4"x1/16", pin
227	2980	30° into	PP(P)	
228	3064	30° into	CP(P)	5 holes: 3(1/4"x1/4"), 2(1/8"x1/8")
229	3070	30° into	CP(P)	11 holes: 2(1/2"x3/8"), 5(1/4"x1/4") 3(1/16"x1/16")
230	3057	30° into	CP(P)	8 holes: 3/4"x1/4", 3(1/4"x1/4"), 4(1/16"x1/16")
231	3039	30° into	PP(P)	
232	3039	30° into	CP(P)	3 holes: 3(1/8"x1/8")
43	3072	60° across	PP(P)	
240	3033	60° across	PP(P)	
241	3021	60° across	PP(P)	

SMALL ARMS FIRING

ROUND-BY-ROUND DATA

Slant Steel and Aluminum Grille
DTA 48462

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
		Caliber .30 Fragment Simulator 45 Grain		
110	2331	0°	PP(P)	
111	2580	0°	PP(P)	
112	Lost	0°	CP(P)	3 holes: 1/2"x1/2", 1/2"x1/8", 1/4"x1/4"
113	Lost	0°	PP(P)	
114	2400	0°	PP(P)	
115	2269	0°	PP(P)	
116	2375	0°	PP(P)	
117	Lost	0°	PP(P)	
118	2529	0°	PP(P)	
124	2384	30° into	PP(P)	Hit bar
125	2518	30° into	PP(P)	
126	2487	30° into	PP(P)	
127	Lost	30° into	PP(P)	Disregard
128	2511	30° into	CP(P)	1 hole: 1/8"x1/8"
129	2498	30° into	CP(P)	2 holes: 3/4"x5/8", 5/8"x5/8"
130	Lost	30° into	PP(P)	
131	Lost	30° into	PP(P)	
132	Low Velocity	30° into	-	Disregard
133	Low Velocity	30° into	PP(P)	Disregard
134	2502	30° into	PP(P)	Hit bar
135	2431	30° into	CP(P)	1 Hole: 3/16"x1/8"
		Caliber .30 Ball		
119	2759	0°	CP(P)	7 holes: 5/8"x1/2", 6 pin
120	2786	0°	CP(P)	1 hole: 5/8"x5/8"
121	2846	30° into	PP(P)	
122	2763	30° into	PP(P)	Hit bar
123	2777	30° into	CP(P)	32 holes: 1-1/2"x1", 3/4"x5/8", 3/4"x1/2" 3(5/8"x5/8"), 5(1/4"x1/4"), 5(1/8"x1/8"), 12(1/16"x1/16") 4 pin.
136	2861	60° across	PP(P)	
137	2800	60° across	PP(P)	
		Caliber .50 Fragment Simulator 207 Grain		
20	2795	0°	CP(P)	3 holes: 1"x1-1/4", 3/4"x1/2", 1/16"x1/16"
21	2838	0°	CP(P)	3 holes: 1"x1", 1/2"x3/8", 1/4"x1/8"

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
22	2768	0°	CP(P)	5 holes: 5/8"x1/8", 2(1"x1"), 1/8"x1/16" 1/4"x1/8"
23	2782	0°	PP(P)	Hit bar
24	2775	0°	CP(P)	1 hole : 1"x3/4"
25	2016	30° into	CP(P)	3 holes: 3/8"x1/4", 1/4"x1/8", pin
26	2734	30° into	CP(P)	5 holes : 1"x1", 5/8"x3/8", 2(1/4"x1/16")
27	2748	30° into	CP(P)	2 holes: 1-1/4"x3/4", pin
28	2810	60° across	PP(P)	
29	2715	60° across	PP(P)	
		0.712 In. Fragment Simulator 600 Grain		
99	2449	0°	PP(P)	Disregard
100	2333	0°	CP(P)	5 holes: 1-1/2"x1", 5/8"x1/2", 1/2"x1/2", 1/8"x1/8", pin - Disregard
101	2234	0°	PP(P)	Disregard
102	2456	0°	CP(P)	11 holes: 5/8"x3/8", 1/2"x1/8", 1/4"x1/4", 2(1/2"x1/8") 3(1/8"x1/8") 3 pin Disregard
104	3053	0°	CP(P)	7 holes: 2"x2", 1"x1", 5/8"x1/2", 3(1/4"x1/4") pin
105	3010	0°	PP(P)	
106	2991	0°	CP(P)	3 holes: 5/8"x1/2", 2(1/2"x1/2")
107	3106	0°	CP(P)	4 holes: 1-1/2"x1-1/4", 1/4"x1/16", 5/8"x1/8", pin
108	1959	0°	CP(P)	4 holes: 1"x3/4", 1-1/4"x1", 2(1/4"x1/4")
109	2981	0°	CP(P)	5 holes : 5/8"x3/8", 2(1/4"x1/4") Pin 1/16"x1/16"
92	2752	0° into	CP(P)	8 holes : 1-3/4"x1-1/4", 1"x3/4", 1"x1/2", 5(1/8"x1/8")
93	2897	0° into	CP(P)	10 holes: 1"x1/8", 4(1/4"x1/4") 1/16"x1/16", 4(1/8"x1/8")
94	1303	0° into	CP(P)	2 hole : Pin - Disregard
95	3091	0° into	PP(P)	Hit spacer bar
96	2912	0° into	CP(P)	6 holes: 1-1/4"x1-1/4", 1"x1", 3/4"x1/4", 1/2"x1/2", 1/2"x1/16", 1/4"x1/16"

Round Number	Striking Velocity	Obliquity	Grille Damage	Number and Size of Holes in Dural - and Remarks
97	2773	0° into	CP(P)	8 holes: 1-1/4"x1-1/4", 1/4"x1/4", 6(1/16"x1/16")
98	2974	0° into	CP(P)	4 holes: 2-1/2"x1-1/4", 1"x3/8", 2(1/16"x1/16")
		20-mm Fragment Simulator		830 Grain
44	3088	0°	CP(P)	14 holes: 1-1/4"x1-1/4", 3/4"x3/4", 2(5/8"x3/8"), 1/2"x1/4", 1/2"x3/8", 3/8"x1/32", 2(1/4"x1/4"), 2(1/8"x1/8"), 3/8"x1/8", 1/4"x1/8", pin
103	[illegible]	0°	CP(P)	11 holes: 1-1/2"x1", 3(1/2"x1/2"), 1"x3/4", 3(1/4"x1/4"), 3(1/8"x1/8")
88	3047	[illegible]° into	-	Disregard
89	3013	30° into	CP(P)	Sheared aluminum bar but missed dural Disregard
90	3032	30° into	CP(P)	1 hole : 2"x1-1/2" - sheared outside aluminum bar
91	3001	30° into	CP(P)	3 holes: 1-1/4"x1-1/4", 5/8"x1/4", 3/4"x5/8"
45	3079	60° across	PP(P)	

APPENDIX C

Procedure for Analyzing Data

In order to derive protection ratings for each type of grille under each attack and to provide a true picture of the protection afforded by the grilles, the following elements of data must be taken into consideration:

a. Percentage of projectiles fired that were defeated by the grille.

b. Average amount of damage sustained by the dural witness sheets from those projectiles which were not completely defeated by the grille.

This combination was effected by taking note of the fact that a projectile that only caused a few small holes in the sheet of dural was substantially defeated by the grille. With this in mind, the percentages were modified to reflect the damage that undefeated rounds were able to produce as designated by letters a, b, c, and d. The letter "a" indicates very minor damage and the letters b, c, and d indicate progressively greater damage. The following is the method that was employed:

Letter Designation	Average Size Hole in Dural
a	Smaller than 3/8 inch.
a-b	3/8 inch to 3/4 inch.
b	3/4 inch to 1 inch.
b-c	1 inch to 1-1/2 inch.
c	1-1/2 inch to 2 inches.
d	Over 2 inches.

Letter Designating Avg Damage to Dural	Amount by Which Percentage is Increased	Typical Example
a	1/2 (100% minus % rds defeated)	60% a = 60 + 1/2 (100 - 60) = 80
a-b	3/8 (100% minus % rds defeated)	60% a-b = 60 + 3/8 (100 - 60) = 75
b	1/4 (100% minus % rds defeated)	60% b = 60 + 1/4 (100 - 60) = 70
b-c	3/16 (100% minus % rds defeated)	60% b-c = 60 + 3/16 (100 - 60) = 68

Letter Designating Avg Damage to Dural	Amount by Which Percentage is Increased	Typical Example
c	1/8 (100% minus % rds defeated)	60% c = 60 + 1/8 (100 - 60) = 65
d	None	60% d = 60

Since the protection ratings are all based on the same criteria, it is possible to compare the protection afforded by a certain grille against attack by any of the projectiles used in the tests, in addition to comparing one grille against another. In the test covered by this report a limited number of rounds were fired; therefore, only differences of five or more are considered significant.

APPENDIX D

Protection Ratings

PROTECTION RATINGS

Caliber .30 Fragment Simulator 45 Grain

Grille	Rounds Fired	Rounds Defeated	% Rounds Defeated	Average Size Hole in Dural	Rating	Average Rating
All Steel						
0°	6	6	100	-	100	
into	3	3	100	-	100	100
across					100	
All Aluminum						
0°	3	3	100	-	100	
into	3	3	100	-	100	100
across	4	4	100	-	100	
Slant Steel & Aluminum						
0°	4	4	100	-	100	
into	9	6	67	.41(a-b)	79	93
across					100	
Straight Steel & Aluminum						
0°	4	4	100	-	100	100
across	3	3	100	-	100	

Caliber .30 Ball

All Steel						
0°	3	1	33	.28(a)	67	
into	3	0	0	.28(a)	50	72
across					100	
All Aluminum						
0°	4	2	50	.28(a)	75	
into	4	4	100		100	75
across	4	0	0	.29(a)	50	
Slant Steel & Aluminum						
0°	2	0	0	.55(a-b)	38	
into	3	1	33	.26(a)	67	68
across	2	2	100	-	100	
Straight Steel & Aluminum						
0°	3	0	0	.25(a)	50	50
across	3	0	0	.35(a)	50	

Caliber .50 Fragment Simulator, 207 Grain

Grille	Rounds Fired	Rounds Defeated	% Rounds Defeated	Average Size Hole in Dural	Rating	Average Rating
All Steel						
0°	10	8	80	.23(a)	90	
into	14	2	14	.27(a)	57	82
across	2	2	100	-	100	
All Aluminum						
0°	8	7	88	.38(a-b)	92	
into	9	9	100	-	100	88
across	16	9	56	.43(a-b)	73	
Slant Steel & Aluminum						
0°	5	1	20	.51 (a-b)	50	
into	3	0	0	.34(a)	50	67
across	2	2	100	0	100	
Straight Steel & Aluminum						
0°	7	3	43	.45(a-b)	64	62
across	2	1	50	1.25(b-c)	59	

0.712 In. Fragment Simulator, 600 Grain

All Aluminum						
0°	3	0	0	.62(a-b)	38	
into	2	2	100	-	100	59
across	3	0	0	.56(a-b)	38	
Slant Steel & Aluminum						
0°	6	1	17	.57(a-b)	48	
into	6	1	17	.40(a-b)	48	65
across					100	

20-mm Fragment Simulator, 830 Grain

Grille	Rounds Fired	Rounds Defeated	% Rounds Defeated	Average Size Hole in Dural	Rating	Average Rating
All Steel						
0° 3000 fps	4	0	0	.17(a)	50*	
0° 2425 fps	7	5	71	.20(a)	86	
into	9	2	22	.18(a)	61	82
across	3	3	100	-	100	
All Aluminum						
0° 3000 fps	2	0	0	1.66(c)	13*	
0° 2425 fps	7	1	14	.59(a-b)	46	
into	8	3	38	.67(a-b)	61	53
across	13	3	23	.67(a-b)	52	
Slant Steel & Aluminum						
0°	1	0	0	.37(b)	50	
into	3	0	0	1.05(b-c)	21	57
across	1	1	100	0	100	

* Not included in average

APPENDIX E

Grenade Detonation Results

RESULTS OF GRENADE DETONATIONS

Grenade Number	Grille	Grenade	Placement of Grenade	Results
1	All Aluminum	M26	Across bars	Dural demolished by blast, aluminum louvers separated.
2	All Aluminum	Mark III	Across bars	Dural demolished by blast, Aluminum louvers separated
3	All Aluminum	Mark III	with bars	Dural demolished by blast, aluminum louvers separated
4	Straight Steel and Aluminum	Mark III	with bars	Dural demolished by blast, aluminum bars sheared off
5	All Steel	Mark III	with bars	Dural demolished by blast, spacer bars ruptured
6	All Aluminum	M26	with bars	Dural demolished by blast, louvers separated
7	Straight steel and Aluminum	M26	with bars	Dural demolished by blast
8	All Steel	Mark III	across bars	Dural demolished by blast, ruptured spacer bars
9	Straight Steel and Aluminum	Mark III	across bars	Dural demolished by blast, 2 aluminum bars sheared off and other aluminum bars blown back, - spacer bars ruptured
10	Slant Steel and Aluminum	Mark III	across bars	Five aluminum bars completely sheared off and penetrated 1/2 inch plywood that was ten inches below grille.
11	Slant Steel and Aluminum	M26	across bars	Two middle aluminum bars completely sheared off. Outside aluminum bars blown back (not ruptured)
12	All Alum inum	M26	across bars	Louvers separated. No fragment damage to plywood
13	All Steel	M26	across bars	Spacer bars separated. No fragment damage to plywood.

APPENDIX F

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