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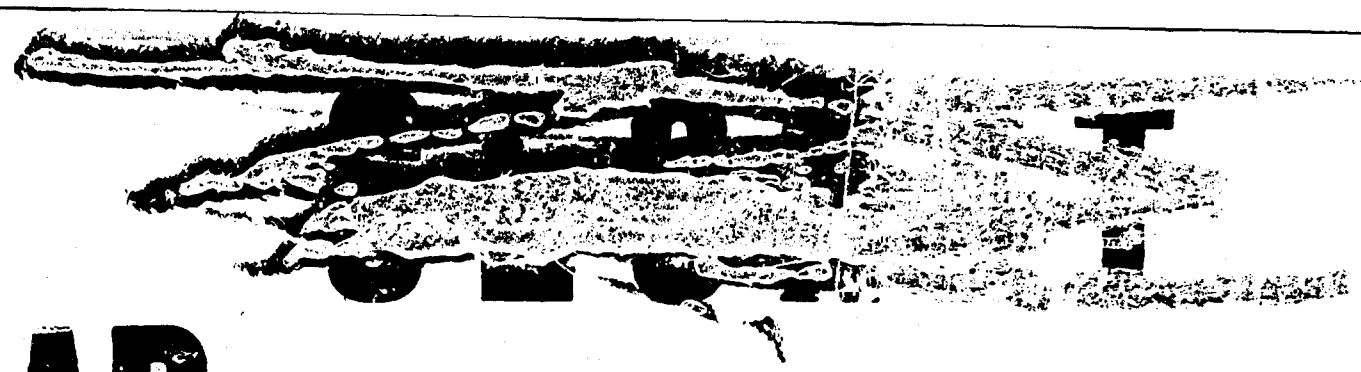

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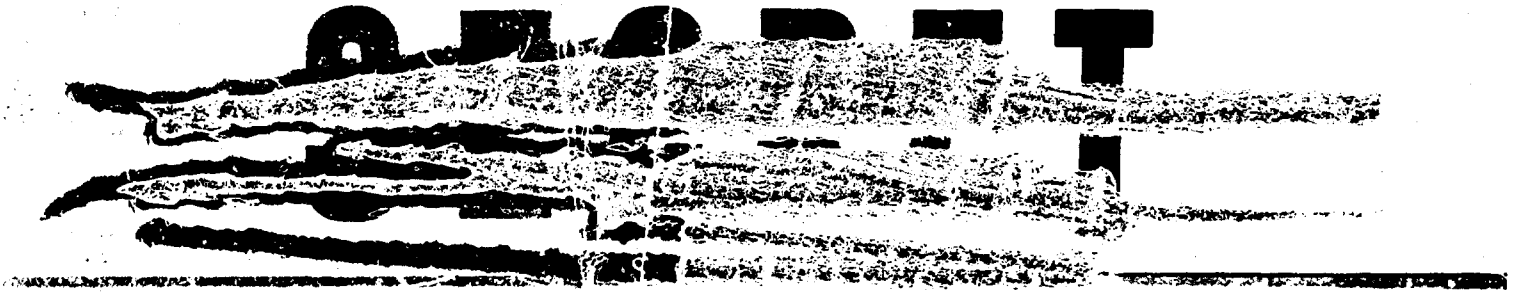

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AUTOMOTIVE DIVISION

REPORT ON

VULNERABILITY EVALUATION OF THE M48 TANK, AND CUPOLAS M1 AND M13, AGAINST SMALL ARMS ATTACK (U)

First Report on OTAC Project No. IT-5098

(AD-1276)

W. B FRYE

AUGUST 1959

Aberdeen Proving Ground
Maryland

DEVELOPMENT AND PROOF SERVICES
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VULNERABILITY EVALUATION OF THE M48 TANK, AND CUPOLAS M1 AND M13, AGAINST SMALL ARMS ATTACK (U)

First Report on OTAC Project IT-5098

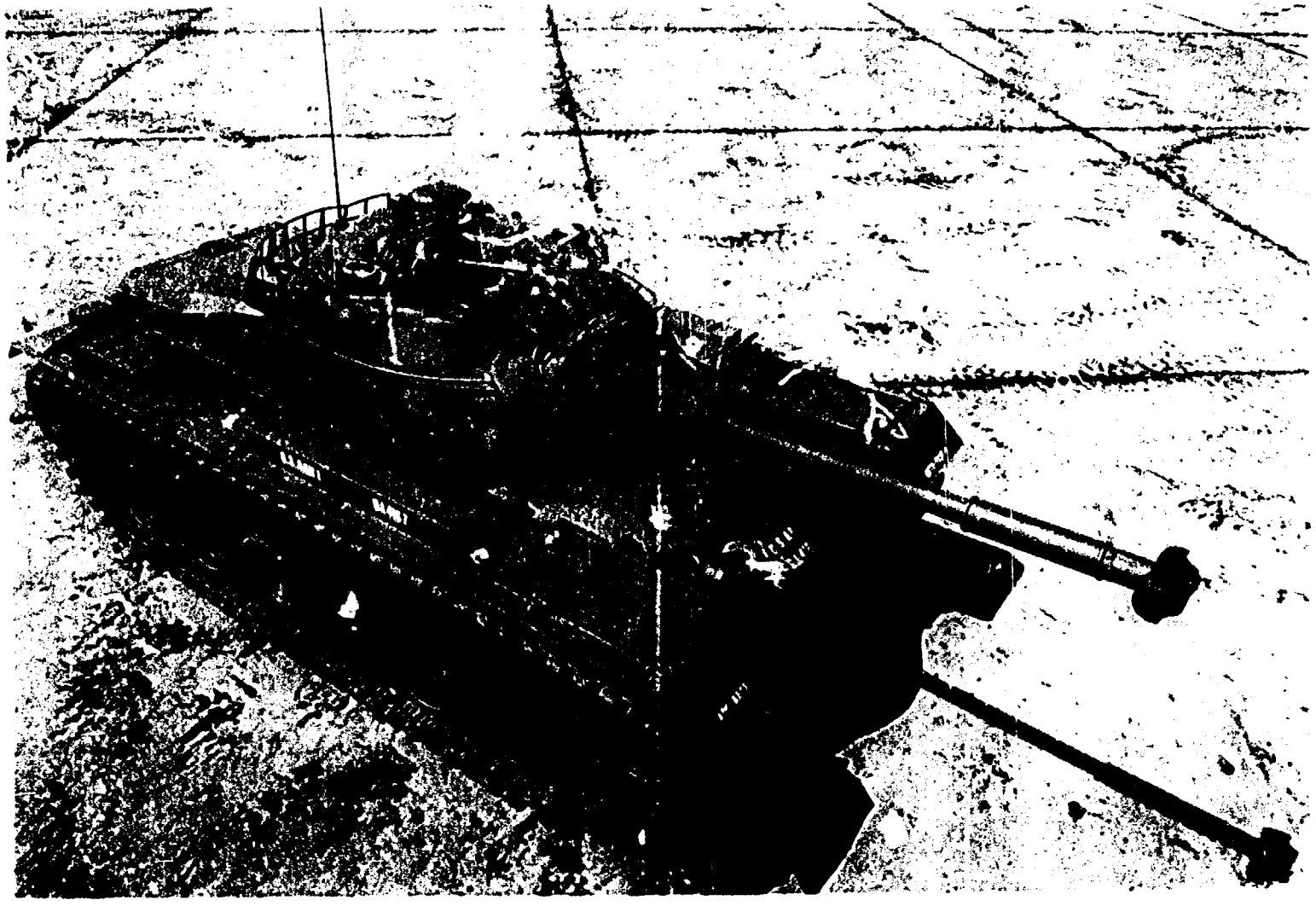
(AD - 1276)

Dates of Test: 8 April to 22 October 1958

ABSTRACT (C)

One M48 tank, three M1 commander's cupolas, and three M13 commander's cupolas were submitted ~~to Aberdeen Proving Ground~~ for ballistic evaluation. Openings on the hull and turret as well as the openings on the cupolas were investigated for passage of bullet fragments into the vehicle and the keying and locking of close-toleranced surfaces by projectile impacts into and adjacent to these areas. Also the direct and indirect vision devices were evaluated as to the protection they afforded against ballistic attack. In the case of the M13 cupolas additional splash guards were installed and tested in an effort to reduce the apparent lethality of the fragment spray which entered the cupola from projectile impacts around the machine gun mantlet and hatch seams. The results of the test indicate that the M48 tank and the two models of cupolas tested can be sufficiently damaged by small-arms fire so as to compel the tank to withdraw from combat. It is recommended that the deficiencies outlined in the test be corrected by redesign of the vulnerable areas or additions of nylon splash shields and armor deflecting strips.

CONTENTS (U)



Frontispiece: Tank, 90-mm Gun, M48A2.

1. (C) INTRODUCTION

The United States Army Armor Board in 1957 conducted limited ballistic tests on the M48 tank (frontispiece) utilizing small arms fired at the various openings on the vehicle. The results of these tests indicated that certain areas and components of the hull and turret were susceptible to damage from small-arms fire; these were the openings around the gun shield, the vision devices, the clearance opening between the turret and hull, and the cupola.

With the existence of these conditions a question arose concerning the actual vulnerability of the M48 tank against ground weapons such as the Soviet 7.62-mm rifle and the Soviet 14.5-mm antiaircraft machine gun.

In view of the results obtained from the Armor Board's test a decision was made by Ordnance Tank-Automotive Command to request Aberdeen Proving Ground to conduct a thorough vulnerability analysis of the M48 tank when attacked with small-arms projectiles. In addition, three M1 commander's cupolas as issued with the M48A2 tank and three M13 commander's cupolas as used on vehicles of the M59 armored personnel carrier class were also submitted for test.

The object of these proposed tests was not only to determine the vulnerability of the previously mentioned areas to bullet splash and projectile penetration but also to ascertain the effect of small-arms projectile impacts possibly keying and locking close-tolerance surfaces. A hindering or immobilization of one or more operations of the main armament would cause the tank to withdraw from combat without accomplishing its assigned mission.

At the beginning it was felt that Soviet weapons and ammunition should be used in conducting these tests. The unavailability of many of these items precluded this desirable feature, hence the comparable U. S. weapons were used.

Table I, comparing NATO/US small arms with their counterpart Soviet weapons, has been prepared to aid the reader in forming a comparison of these weapons.

Table I. (S) Summary of NATO/US vs Soviet Small Arms

NATO/US			SOVIET		
M14 Rifle			SKS-Semi-Automatic Carbine		
Caliber - 7.62-mm NATO			Caliber - 7.62-mm M1943 Short		
(1)	(2)	(3)	(1)	(2)	(3)
Ball	146.5	2750	Ball	122	2411
API	146	2750	API	119	No data available
M60 Machine Gun			SG-43 Machine Gun (Goryunov)		
Caliber - 7.62-mm NATO			Caliber - 7.62-mm Long		
(1)	(2)	(3)	(1)	(2)	(3)
Ball	146.5	2750	Ball	185	2625
AP	146.5	2750	AP	184	2625
Browning Machine Gun, HB, M2			DShK M1938 Machine Gun[a]		
Caliber .50			Calib - 12.7-mm		
(1)	(2)	(3)	(1)	(2)	(3)
AP	718	2930	AP	788	2822
API	622	3050	API	745	No data available
APIT	624	3050	APIT	681	No data available
			Penetration = 0.71 in. at 600 yd.		
T17E5 Machine Gun (Discontinued)			ZPU Machine Gun[b]		
Caliber .60			Caliber - 14.5-mm		
(1)	(2)	(3)	(1)	(2)	(3)
API	1146	3510	API	979	3281
			API	994	3281
			with Tungsten core		
			Penetrates 0.79 in. at 1100 yd.		

NATO/US			SOVIET		
M24 Automatic Aircraft Cannon			VYa Automatic Aircraft Cannon		
Caliber - 20-mm			Caliber - 23-mm		
(1)	(2)	(3)	(1)	(2)	(3)
API	2000	2730	API	3019	2980
HEI	2038	2730	HEIT	3086	2980

(1) = Type projectile; (2) = Grain weight of projectile;
(3) = Muzzle velocity.

[a] Information reveals this weapon is used singly on a ground mount by the Soviet forces and on a quadruple mount by the Czech Army.

[b] Data available indicates this weapon may be encountered singly, in twins and in quadruple mounts and its use is extensively employed by the Soviet forces.

The information on the Soviet small arms was supplied by the Ordnance Technical Intelligence Office, Aberdeen Proving Ground, Maryland.

2. (U) DESCRIPTION OF MATERIEL

One Tank, [illegible] M48, Serial No. USA 9A6943 was made available by OCO for this test. In addition three M1 commander's cupolas and three M13 commander's cupolas were also submitted for test.

3. (C) DETAILS OF TEST

3.1 Procedure

The damage assessments made during this test were performed in accordance with the criterion agreed upon during the Fourth Tripartite Conference on Armor held in Quebec, P. Q. Canada on 21 to 25 October 1957. This criterion is listed below:

a. A tank is knocked out if the main armament is put out of action either because the crew has been rendered incapable of operating it or because the armament or its associated equipment has been so damaged as to render it inoperative and irreparable by the crew on the battlefield.

b. A tank is immobilized if it is incapable of executing controlled movement and is irreparable by the crew on the battlefield.

c. A tank is destroyed if it is knocked out, immobilized and damaged beyond repair.

This criterion has been applied to the test results in the left-hand margin of the results section of this report, using the same numerical designation as used above.

On each projectile impact that caused damage to the vehicle and required immediate repair before proceeding with the test, the total number of hours for effecting this repair has been recorded. These total hours are based on the use of an experienced three-man crew, the availability of an overhead crane at the test site, readily accessible flame-cutting and welding equipment, and all daylight hours of operation. Thus it can be readily seen that under combat conditions and possibly night operation considerably more time might be required to effect repairs of the nature covered in this report.

In order to avoid confusion over the many areas and components subjected to a ballistic test in this program the testing was divided into two stages. Stage I dealt with the M48 tank and M1 cupolas and Stage II reports the results obtained in the testing of the M13 cupolas. Each stage was further subdivided into phases which referred to explicit areas, components or conditions of attack.

3.2 Results

3.2.1 Stage I. Phase I. The initial phase of testing consisted of impacting small-arms projectiles into the 1/2-inch opening between the turret and hull. This was done in an attempt to key or immobilize the turret, thus eliminating or reducing the efficiency of the main armament of the tank.

3.2.1.1 Direct Frontal Attack. Ten rounds of caliber .30, AP, M2 projectiles were first fired into this opening. No damage to the traversing operation resulted from these impacts; however, one round did produce a condition which required a slight extra effort to achieve manual traverse to the left. This condition was quickly overridden and gave no additional trouble.

The turret was completely locked in left traverse by one round of caliber .50 ball, M2 ammunition impacting in this opening. This projectile penetrated the 5/16-inch dust or labyrinth ring that was tack-
a. welded to the hull. A 3-1/4 inch section of this ring was sheared off at one tack weld and petalled into the corresponding dust ring of the turret with sufficient force to prevent any left traverse of the turret.

To relieve this condition it was necessary to remove the turret from the vehicle before the petalled portion of the ring could be removed. This work was accomplished in five hours (Figure 1).

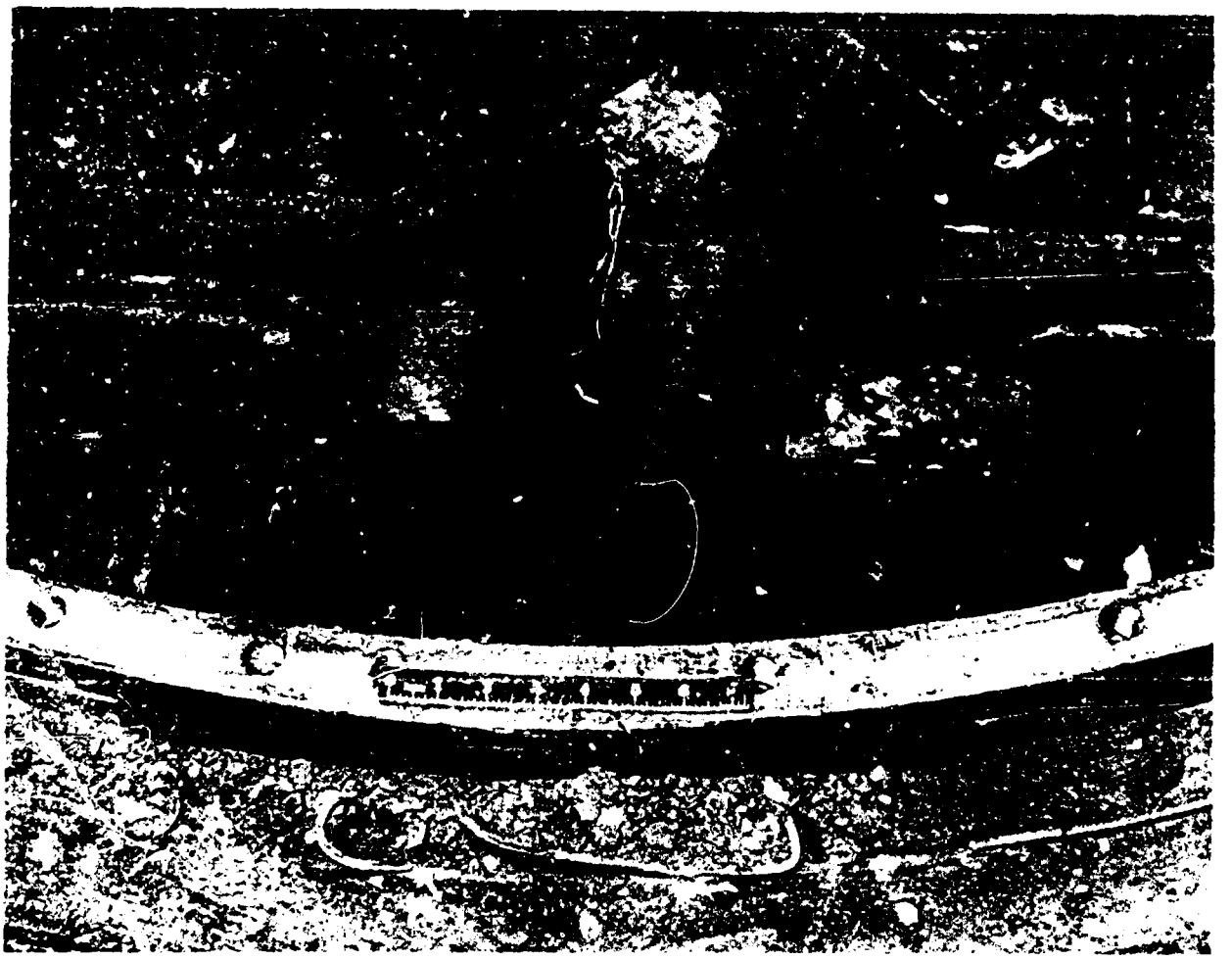


Figure 1 - B29651: Typical Damage To Hull Labyrinth Ring When Impacted With Caliber .50 Ball Projectiles.

The next stage of testing consisted of firing five rounds of caliber .50, API, T69 projectiles into this opening with the following results noted. Round 1 resulted in a slight hindrance to left traverse but was easily overridden manually and gave no additional trouble after the initial effort. Round 3 impacted 1-1/4 inches below the hull mounting ring and scooped upward into the flat portion of this ring area raising 1/4-inch-high petals but did no damage to the traversing operation. Round 4 hit 3/4 inch above
a. the bottom edge of the turret and produced a bowing or bulging effect extending downward 3/8 inch. When assessed alone neither of these impacts had any

effect on the traversing operation but would stop all traverse when the two areas would contact each other. This condition was relieved in 5 minutes by cutting off the petals on the hull with a cold chisel. Round 5 wedged a 4-inch section of the hull dust ring against the turret ring in such a manner as to permit only a 34° right traverse and a 270° left traverse. The turret had to be removed from the vehicle to relieve this condition and restore free traverse. Approximately 4-1/2 hours were utilized in correcting this condition.

a. 3.2.1.2 90° Flank Attack. One round of 20-mm, AP, M95 was fired in a direct flank attack through a fender box, impacting 1 inch below the opening between the turret and hull. This projectile scooped upward into the base of the turret, closing the 1/2-inch opening and locking the turret in the traverse operation. Fifteen minutes of labor with a cutting torch was required to free the turret (Figure 2).

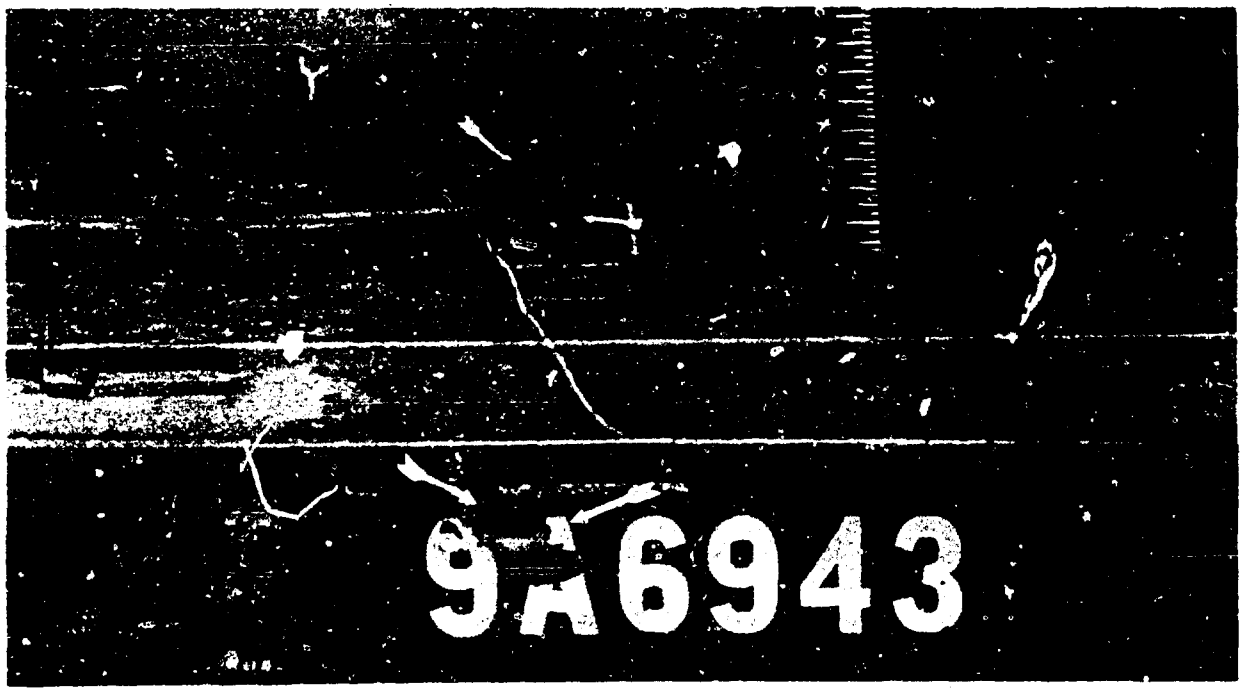


Figure 2 - B29723: Turret Locked in Traverse by 20-mm, AP, M95 Projectile Penetrating Fender Box and Impacting into Turret and Hull Opening.

3.2.1.3 15° Overhead Attack. In an effort to ascertain the height of the vulnerable area above the 1/2-inch opening between the turret and the hull, several rounds of caliber .60 and 20-mm projectiles were impacted on the lower edge of the side wall of the turret at predetermined distances above the opening. This was done to determine the possibility of impacts from overhead fire, as from strafing aircraft, striking on the lower edge of the turret and sufficiently depressing the armor so as to close the 1/2-inch opening, causing a keying condition on the hull surface and thus locking the main armament in traverse operation.

a. Two rounds of caliber .60, API, T39 projectiles impacted at 3/8 inch and 5/8 inch, respectively, above the bottom edge of the turret, succeeded in depressing the armor along the edge, closing the 1/2-inch opening and completely locking all traverse operation of the turret (Figure 3). One projectile impacting 3/4 inch above this opening resulted in a locking of the left traverse only. In each of the three preceding instances 10 minutes of labor with a cutting torch was required to restore the turret to normal operation.

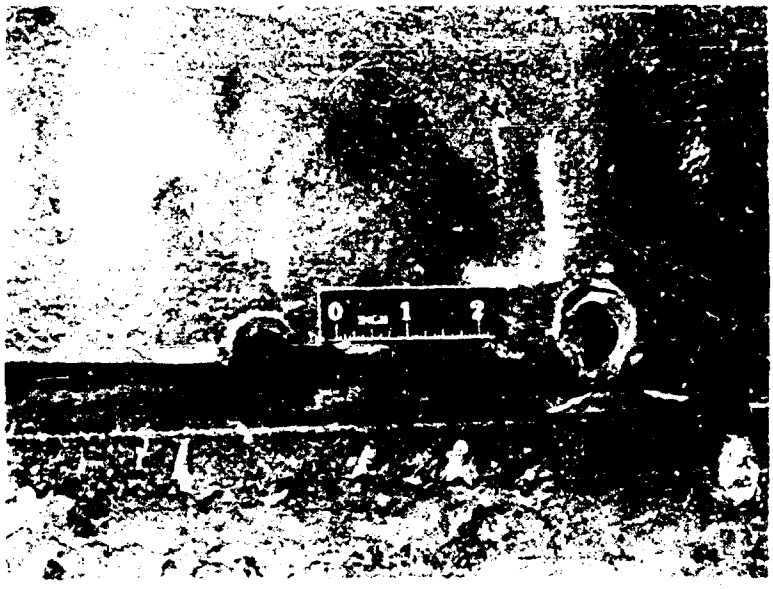


Figure 3 - B29722: Turret Locked In Traverse Operation by Caliber .60, API, T39 Projectile Impact.

One round of caliber .60, API, T39 was impacted on the hull ledge beneath the bottom edge of the turret to determine if projectiles impacting in this area would ricochet upward into the bottom edge of the turret and hamper the traversing operation. This projectile scooped into the opening between the hull and turret, bending the hull dust ring into a hook shape and jamming the turret in left traverse. Approximately three hours were required to remove the turret from the vehicle, cut off the dust ring and reassemble the turret to the hull.

a. Two rounds of 20-mm, AP, M95 projectiles were also impacted against the bottom edge of turret from the 15° overhead position. One projectile striking 3/8 inch above the bottom edge of the turret failed to produce any hindrance to the traversing operation. The second round, impacting 1/2 inch above the bottom edge of the turret, penetrated the turret on a downward course with the projectile nose keyed in the flat hull surface beneath the turret edge. This impact

completely locked all traversing operations. Four hours were required to remove the turret, relieve the keying condition and reassemble the turret to the vehicle.

The round-by-round data for Phase I are contained in Appendix B.

3.2.2 Stage I. Phase II. The second phase of testing consisted of an evaluation of the protection afforded by the M36 (T36) driver's periscopes when subjected to attack with small-arms projectiles. During testing each periscope was placed in the forward periscope slot in the driver's compartment and subjected to a projectile impact as follows:

No. of Periscopes	Projectile	Type of Attack
2	Cal .30, AP, M2	0° - Normal to block.
4	Cal .50, AP, M2	0° - Normal to block.
2	20-mm, AP, M95	15° Overhead - Normal to block.

The two periscopes attacked with the caliber .30, AP, M2 projectiles suffered 50% and 85% destruction of visibility, respectively. No glass fragments were displaced from either eye prism and each periscope could have been readily replaced by the driver from within the vehicle without outside assistance (Figure 4).

Three of the periscopes impacted with the caliber .50, AP, M2 projectiles sustained 100% destruction of visibility. In each of these three instances the plastic body of the periscope was sheared and the top prism completely displaced from its normal position (Figure 5). In all three of these cases the driver would have been able to effect a rapid, unassisted change from within the vehicle under fire. The fourth periscope in this group suffered 75% destruction of visibility and no shearing of the plastic body occurred. Although this item suffered the least damage of the four periscopes attacked with the caliber .50 projectiles it was this last unit which would have caused the tank crew the most trouble in making a replacement under fire. A 2- by 2-5/8 inch opening on the rear of the metal top prism frame petalled out over the limits of the periscope slot and would not permit the periscope to be withdrawn into the driver's compartment for replacement without assistance from someone on the exterior of the vehicle (Figure 6). The eye prisms of the four periscopes were badly cracked but no glass fragments were displaced to injure the driver's eyes, although some glass dust was observed to filter down into the driver's compartment as a result of the projectile impacts in the upper prism.

The two periscopes impacted with the 20-mm, AP, M95 projectile from a 15° overhead attack suffered 100% destruction of visibility. Both plastic bodies were sheared off at the top of the eye prism and the top sections were completely displaced from the periscope slot. On one periscope two glass fragments measuring 15/16 by 1/2 inch and 7/16 by 1/8 inch were displaced from the eye prism. None of the displaced fragments retained a residual

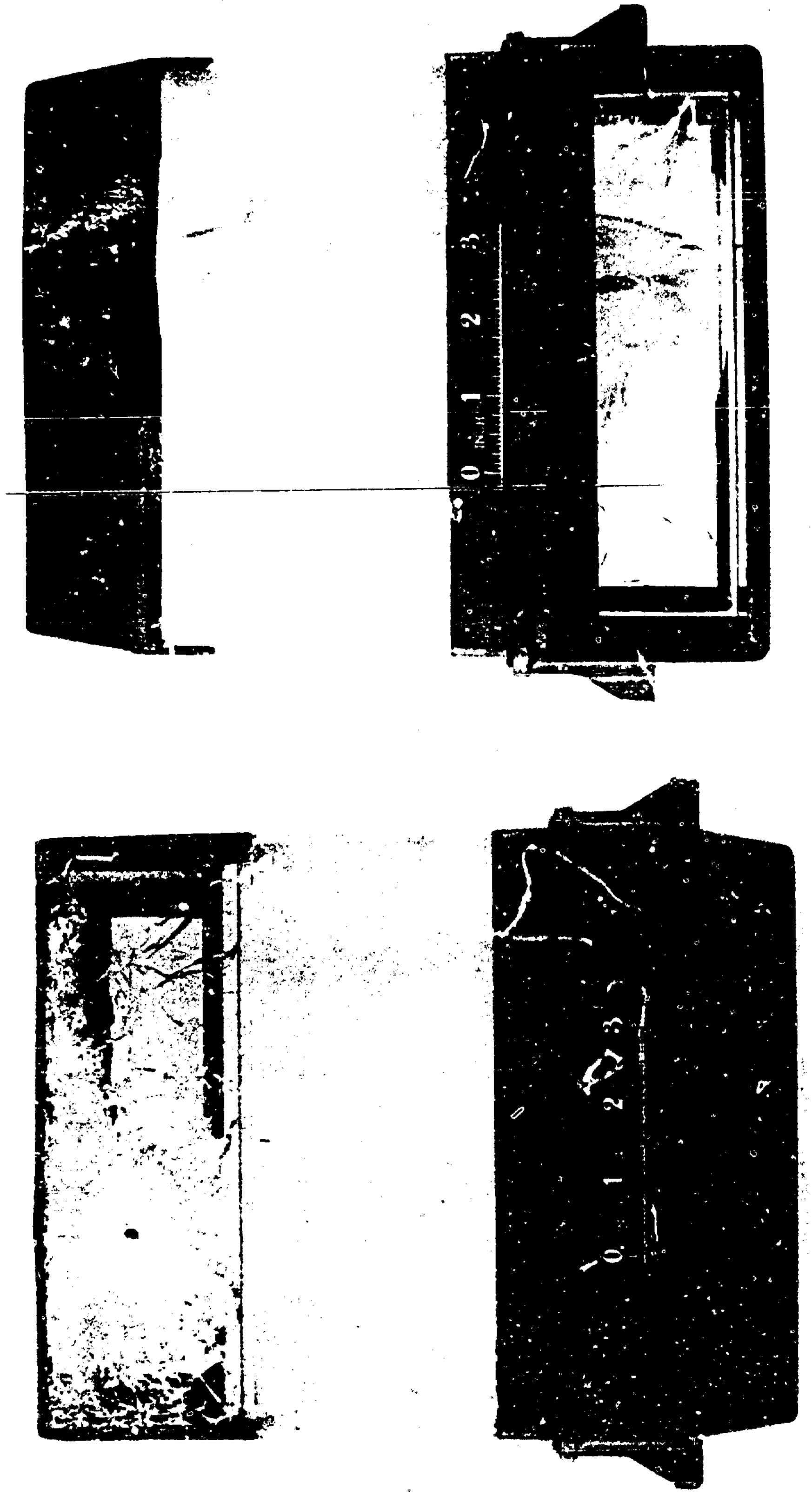


Figure 4 - 59T2090 (Left) and 59T2091: Front Surface (Left) and Rear Surface Views of One M36 Driver's Periscope Impacted with One Round Caliber .30, AP, M2 Projectile.

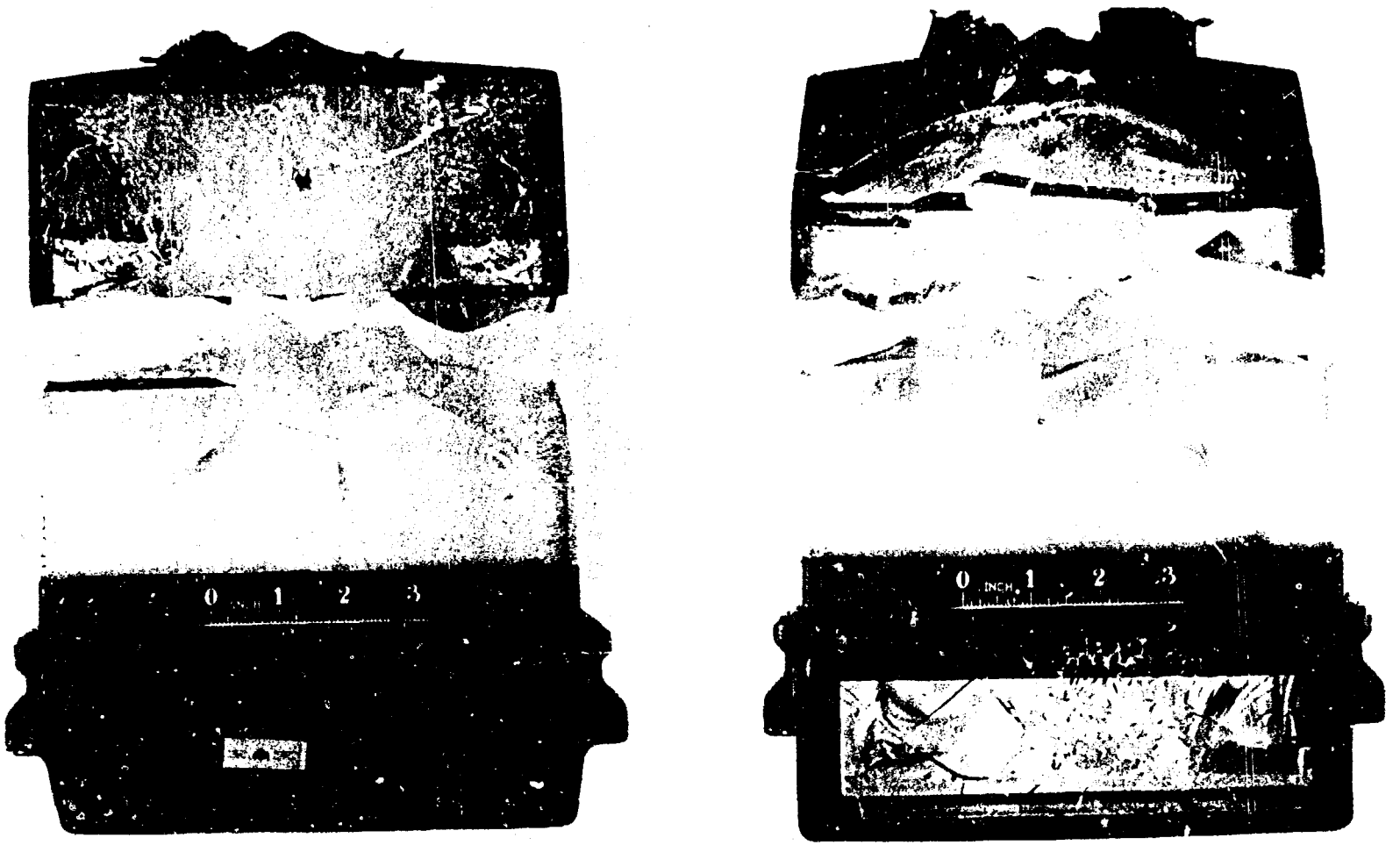


Figure 5 - 59T2092 (Left) and 59T2093: Front Surface (Left) and Rear Surface Views Showing Fracturing of Plastic Body of M36 Driver's Periscope When Attacked with a Caliber .50, AP, M2 Projectile.

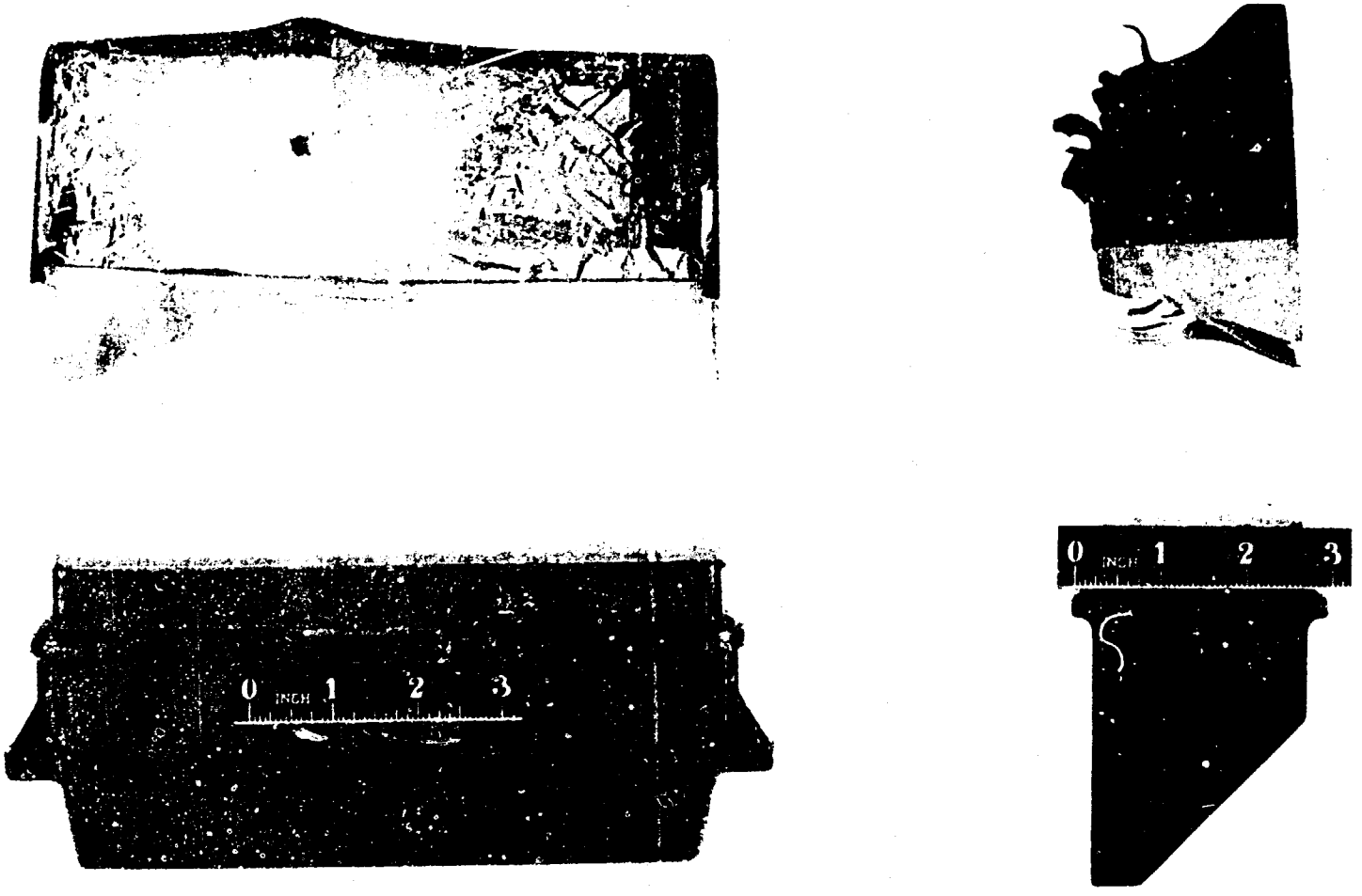


Figure 6 - 59T2096 (Left) and 59T2097: Front Surface (Left) and Side Surface Views Showing Petalling of Objective Prism Metal Case Caused by One Impact of a Caliber .50, AP, M2, Projectile.

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velocity sufficient to mark a piece of light cardboard suspended behind and underneath the periscopes. Some glass dust did filter down through the periscope opening into the driver's compartment as a result of the projectile impacts shearing the plastic bodies (Figure 7).

In one instance the 20-mm, AP, M95 projectile, after passing through the top prism of the periscope, scooped across the hull top and locked the driver's hatch in the closed position. This hatch could not have been freed by the driver from the interior of the tank. Twenty minutes of labor by two men, working on the exterior of the vehicle, using hammers, cold chisels, and wrecking bars was required to release this hatch (Figure 8). The round-by-round data for Phase II are contained in Appendix C.

3.2.3 Stage I. Phase III. The third phase of testing consisted of an attempt to key or lock the main armament of the tank by impacting 20-mm, AP, M95 projectiles in and around the mantlet or gun shield. All firing in this phase was conducted from a 15° overhead attack simulating aircraft fire.

The first stage of this phase consisted of a 90° flank attack, measured 90° off the longitudinal axis of the turret on the right side with the 20-mm, armor-piercing projectile fired into the area between the forward edge of the turret and the rear of the gun shield. Four impacts in this area failed to produce any hindrance to the elevating or depressing operation of the main weapons. One round did penetrate the coaxial telescope mounting area in the mantlet and would have destroyed the usefulness of this scope had one been mounted in position.

Two rounds were fired at the top of the mantlet between the turret and gun shield in a direct flank condition in an effort to wedge the projectile in the opening between the top of the shield and turret, thereby locking the gun in elevation and depression. Both rounds were observed to ricochet harmlessly off the mantlet and neither impact caused any damage to the elevating or depressing operation of the main weapon.

No testing was conducted in a direct frontal attack condition due to the fact that the opening on the front of the turret is adequately protected against overhead attack by the mantlet or gun shield with the 90-mm gun at 0° elevation.

The round-by-round data for Phase III are contained in Appendix D.

3.2.4 Stage I. Phase IV. The fourth phase of testing consisted of an attempt to immobilize the traversing operation of the M1 commander's cupola mounted on the M48A2 tank. Testing in this phase was conducted from a 15° overhead position simulating battle strafing aircraft attack and enemy small-arms fire from elevated positions such as hilltops and the second or third story of a building. The cupola was subjected to attack by caliber .30, AP, M2, caliber .50, AP, M2 and caliber .60, API, T39 projectiles.

Figure 7 - 59T2094 (Left) and 59T2095: Front Surface (Left) and Rear Surface Views of One 136 Driver's Periscope, Showing Damage From One 20-mm, AP, 195 Projectile Impact - White Arrows on Rear Surface View Denote Areas From Which Glass Fragments Were Displaced.

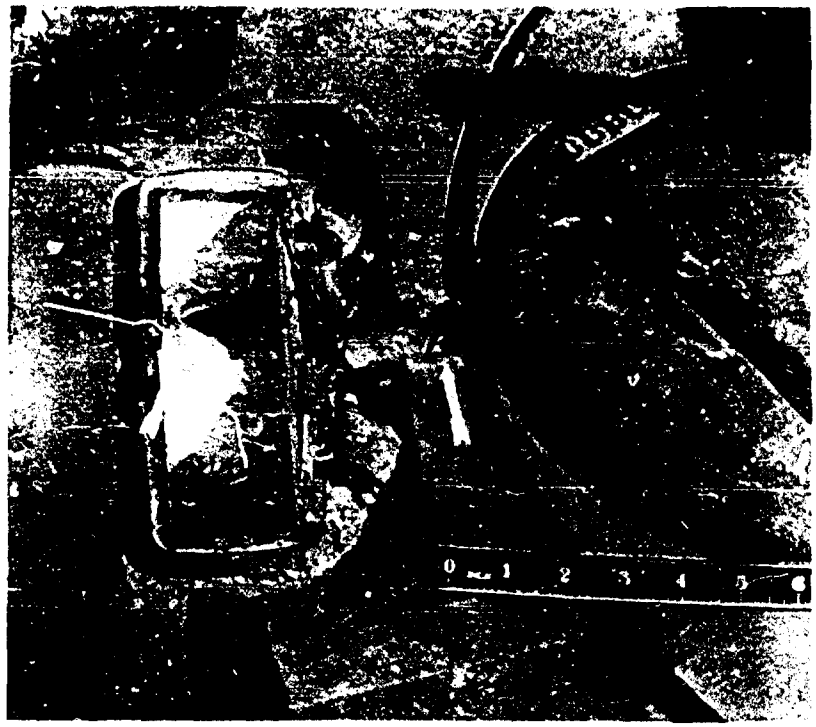

Figure 8 - B29721: Objective Prism Displaced and Driver's Hatch Keyed Shut by One Impact of a 20-mm, AP, M95 Projectile.

Six rounds of caliber .30, AP, M2 projectiles were fired into the area at the base of the cupola and the top of the turret. None of these impacts produced a keying condition that hindered the traversing operation of the cupola.

A total of six rounds of caliber .50, AP, M2 projectiles were fired into this area with a partial keying condition resulting from one impact. In this instance the core of the projectile passed through the base rim of the cupola, fractured, and left a piece of the core sticking in the top of the turret beneath the cupola. The cupola could not be traversed to the left from its position at point of impact but could be traversed 360° to the right until contact was made between the damaged areas on the underside of the cupola and turret top. One hour was required to pull the cupola and clear the ring area using hammers and cold chisels to restore the traversing operation. No damage to the operation of the cupola was noted on the remaining five impacts.

Two rounds of caliber .60, API, T39 projectiles were also fired at the base of the cupola. Both rounds succeeded in completely locking the cupola in position. In the case of Round No. 1, a 1-7/8 inch section of the cupola dust ring was displaced and lodged against the turret, locking the

cupola in place. In addition, the retaining ring on the underside of the cupola was bowed downward 3/4 inch, resulting in a locking condition on the turret top. One hour was required to relieve these locking conditions and put the cupola back into operation. The small section of dust ring was removed with a hammer and cold chisel and the bowed section of the retaining ring was removed by flame cutting. It should be noted that after the section of the retaining ring was removed the traversing operation of the cupola was not so easily accomplished due to the loss of some of the plastic ball bearings from the cupola ring. However, had a spare cupola not been readily available this tank could have been back in action in one hour as a result of these hasty repairs. The second impact with a caliber .60, AP projectile also locked the cupola in the traverse operation. In this instance a large bow of the retaining strip measuring 4 inches along the cord line and 3/4 inch in depth locked the cupola to the turret top. No effort was made to repair this damage.

The round-by-round data for Phase IV are contained in Appendix E.

3.2.5 Stage I. Phase V. This phase consisted of ballistic attacks on the cupola vision blocks with caliber .30 and .50 armor-piercing and ball ammunition. The blocks were subjected to attacks from 15° overhead and 0° to the block with the caliber .50, and at 15° overhead attack with with the caliber .30.

Large pieces of glass were displaced from the rear of the two vision blocks attacked with the caliber .50, AP, M2 projectiles, fired from 15° overhead. All of the blocks suffered a complete penetration by the projectile and the other block deflected the projectile upward into the top of the vision block frame in the cupola wall. In view of the apparent vulnerability of the vision blocks to the caliber .50, AP projectiles in this attack condition, one vision block was subjected to attack with a caliber .50 ball projectile fired from the 15° overhead position. In this case the core of the projectile penetrated the vision block causing damage to the block similar to that caused by the armor-piercing projectiles.

In an effort to evaluate the efficiency of a metal-rimmed clear plastic shield, provided by Detroit Arsenal, two rounds of caliber .50, armor-piercing ammunition utilizing reduced charges were next impacted against two vision blocks. This metal-rimmed clear plastic shield was fabricated to a slightly larger configuration than the rear surface of a vision block and was mounted to the rear of the block by the three bolts locking the block-retaining wedge in place. The purpose of these shields was to determine if such an item would effectively trap any small fragments or glass dust which might be dislodged from the rear of a vision block by projectile impacts, hence adding further protection for the tank commander's eyes (Figure 9). These two rounds were fired at an estimated striking velocity of 2500 fps. On the first block, without the shield, the projectile lodged in the block, displaced two large fragments plus

numerous small fragments and glass dust from the rear of the block. The second block, with the shield in place, was penetrated by the projectile and the shield was destroyed.

The next stage of testing consisted of impacting two vision blocks with the caliber .30, AP, M2 projectiles, fired at service velocity, from the 15° overhead position. Neither block was penetrated by the projectiles but some fine glass fragments were displaced from the rear of each block. The fragments off the second block were effectively trapped and contained by the experimental shield.

Figure 9: Metal-Rimmed Shield With Clear Plastic Removed.

The last two vision blocks were tested with the caliber .50, AP, M2 projectiles, fired at service velocity, at 0° elevation normal to the glass. As in the case of the latter two blocks, neither one was penetrated by the projectile but some fine glass fragments were displaced from the rear surface. Again the experimental shield effectively trapped all fragments displaced from the second block.

The round-by-round data for Phase V are contained in Appendix F.

3.2.6 Stage I. Phase VI. The sixth phase of testing consisted of subjecting the M1 cupola to bullet-splash and keying tests around the machine gun (MG) mantlet or cradle and the hatch cover on the rear of the cupola. In order to ascertain the density of bullet splash caused by ball ammunition striking and breaking up in or near the various openings of the cupola each area tested was sealed off with heavy brown (Kraft) wrapping paper on the interior of the cupola. The caliber .30, ball, M2 projectile, fired at service velocity, was used throughout the testing conducted in Phase VI.

The first area tested for bullet splash was the opening on the right front surface of the MG cradle through which the barrel support and barrel of the caliber .50 MG protrude. Testing was accomplished with a caliber .50 MG in position with the ballistic ring in place. This ring clamps over the rear portion of the barrel support, which remains within the interior of the cradle and is designed to close any tolerance between the barrel support and opening in the cradle when the MG is positioned in the cupola. The two rounds of caliber .30 ball ammunition impacted in this area resulted in the passage of numerous fragments into the cupola as shown in the following tabulation:

Round No.	Size of Fragment Holes in Splash Paper			
	1 in.	3/4 in.	1/2 in.	1/8 in.
1	0	1	1	34
2	1	0	1	57

The second projectile impact located in this area sheared the ballistic ring locking strap and bent the ring out of line (Figure 10).

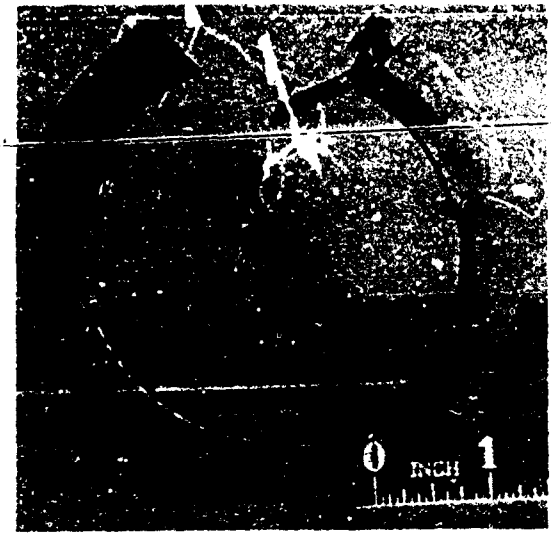

Figure 10: Damage to Ballistic Ring Resulting From One Impact of Caliber .30 Ball Ammunition.

The second area, the opening on the side between the MG mantlet and the front of the cupola, was tested for a keying condition. This area was subjected to a direct flank attack with the weapon at 0° elevation. One round of caliber .30 ball ammunition impacting in this opening completely locked the MG in elevation and depression. Fifteen minutes of work with harmers and cold chisels was required to release this keying condition.

The third area, the opening between the bottom of the MG cradle and the bottom of the cradle opening, was subjected to a bullet-splash test fired as a direct frontal attack with the MG in maximum elevation. Three rounds of caliber .30 ball projectiles were impacted into this opening and produced such a dense fragment pattern in the cupola that the Kraft paper was completely destroyed after each round.

The seam around the sides of the hatch on the rear of the cupola was the fourth area tested in this phase. This seam was subjected to a bullet-splash test with caliber .30 ball projectiles. Three rounds were impacted on this seam and no fragment passage into the cupola was noted.

The last area subjected to a bullet-splash test on the M1 cupolas was the seam at the bottom of the cupola hatch and the base of the cupola. Two rounds of caliber .30 ball projectiles impacted on this seam resulted in the passage of fragments into the cupola as follows:

Round No.	Size of Fragment Holes in Splash Paper				
	3/4 in.	1/2 in.	3/8 in.	1/4 in.	1/8 in.
1	2	1	1	4	103
2	0	0	0	1	62

The first projectile impacted 1-1/8 inches right of the left bottom edge of the hatch cover. A 5/8-inch hole was noted in the fragment trap or dust ring on the cupola base as a result of this impact. The second round impacted 5/8 inch right of Round No. 1, displacing a portion of the rubber water seal around the perimeter of the hatch cover.

The round-by-round data for Phase VI are contained in Appendix G.

3.2.7 Stage I. Phase VII. The final phase consisted of resistance-to-penetration tests of the armor of the M1 commander's cupola. As outlined in the directive protection ballistic limits were to be obtained on the cupola from a 15° overhead position and also at 0° elevation.

The first area subjected to a resistance-to-penetration test was the machine gun mantlet with a measured obliquity of 35°. This area was attacked with the caliber .50, AP, M2 projectile fired from the 15° overhead position. The second area test was the right side of the cupola, above the vision blocks, with an obliquity of 42°. Thickness measurements of this area ranged from 1.08 inches to 1.25 inches with an average thickness of 1.17 inches. This section was attacked with the caliber .50, AP, M2, and 20-mm, AP, M95 projectiles fired from the 15° overhead position. The third area subjected to the resistance-to-penetration tests was the hatch at the rear of the cupola. Thickness measurements in the area subject to ballistic attack ranged from 0.84 inch to 0.94 inch with an average thickness of 0.89 inch, and a 37° obliquity. This area was attacked with the 20-mm, AP, M95 projectile fired from the 15° overhead position from direct rear.

In none of the three areas outlined above was it possible to obtain a protection ballistic limit. No complete penetrations of the cupola armor resulted from projectile impacts although in each condition of attack the striking velocities of the impacting projectiles exceeded the muzzle velocities of service ammunition for their respective calibers.

The round-by-round data for Phase VII are contained in Appendix H.

3.2.8 Stage II. Phase I. The first area of the M13 cupolas subjected to a bullet-splash test was the opening for the caliber .50 MG in the right front surface of the MG cradle. This area was subjected to three impacts by caliber .30 ball ammunition around the perimeter of the caliber .50 MG barrel support and none of the fragments from these rounds was observed to enter the interior of the cupola.

The second area subjected to a bullet-splash test was the opening between the bottom edges of the MG cradle and the cupola ring. One round of caliber .30 ball ammunition was fired to impact 1 inch above the bottom edge of the cradle in a direct frontal attack with the MG in maximum elevation. This round resulted in such a dense fragment spray into the cupola that the Kraft paper was destroyed. In view of this result testing in this area was suspended.

The third area tested for a bullet-splash condition was the cupola hatch seam. This area was subjected to a 90° flank attack with two rounds of caliber .30 ball ammunition. As a result of these two impacts on this seam the following fragments were noted to have entered the cupola:

	Hole Size In Splash Paper				
Round No.	3/4 in.	1/2 in.	1/4 in.	1/8 in.	Total
1	0	2	0	5	7
2	1	3	4	14	22

A 3-3/4 inch section of the dust shield was also bent out of shape as a result of Round No. 2.

The round-by-round data for Phase I are contained in Appendix I.

3.2.9 Stage II. Phase II. The second phase of testing was also a bullet-splash test with special splash guards welded into place around the MG cradle and hatch-cover seam. These special splash guards were assembled to the cupola at this proving ground. These guards were installed to very close tolerances around the openings in an effort to reduce the lethal fragment spray entering the cupola.

The first area subjected to test with the new guards in place was the opening between the bottom of the MG cradle and the cupola base. Two rounds of caliber .30 ball were fired at this opening, one at the bottom edge of the cradle and one directly into the opening with the MG in maximum elevation. Both impacts resulted in such a dense fragment spray entering the cupola that the Kraft paper was completely destroyed. On the third impact into this area the cradle was depressed four turns under maximum elevation and the projectile impacted on the cradle 1 inch above the opening. One 5/16-inch, one 1/4-inch and twenty-two 1/8-inch perforations from fragment spray were recorded on the Kraft paper (Figure 11).

In an effort to effectively trap the consistent fragment spray through this opening an aluminum shield was clamped to the cupola frame to the rear of the MG cradle. This aluminum shield was used in addition to the splash guards that had been installed previously.

Figure 11: Black Arrows Indicate Splash Guard Installed at Bottom of MG Cradle and Cupola Base.

Three rounds of caliber .30 ball ammunition were fired in this area with the following results:

Rd No.	Location of Impact	Fragment Size 1/8 in.	Fragment Size 1/16 in.	Total	Damage to Aluminum Shield
1	On the opening	Destroyed paper		-	Badly bent
2	1-1/4 in. above opening	11	11	22	No damage
3	3/4 in. above opening	Destroyed paper		-	Badly bent

The above rounds impacted on the cradle from a direct frontal attack with the MG cradle in maximum elevation.

The next area subjected to a bullet-splash test with the splash guards welded in place was the opening between the top of the MG cradle and the cupola top. This area was subjected to an impact with one caliber .30 ball projectile fired from a 30° overhead attack with the MG in maximum depression. This projectile struck on the top edge of the cradle, glanced into the opening and the resulting fragment spray destroyed the Kraft paper (Figure 12).

The final area to be tested against bullet splash with the new splash guards in place was the seam at the base of the cupola hatch and the cupola base ring. One round of caliber .30 ball ammunition hit directly on the opening, and produced one 1/8-inch hole and thirty 1/16-inch holes in the Kraft paper. The aluminum shield which was in place for this impact was

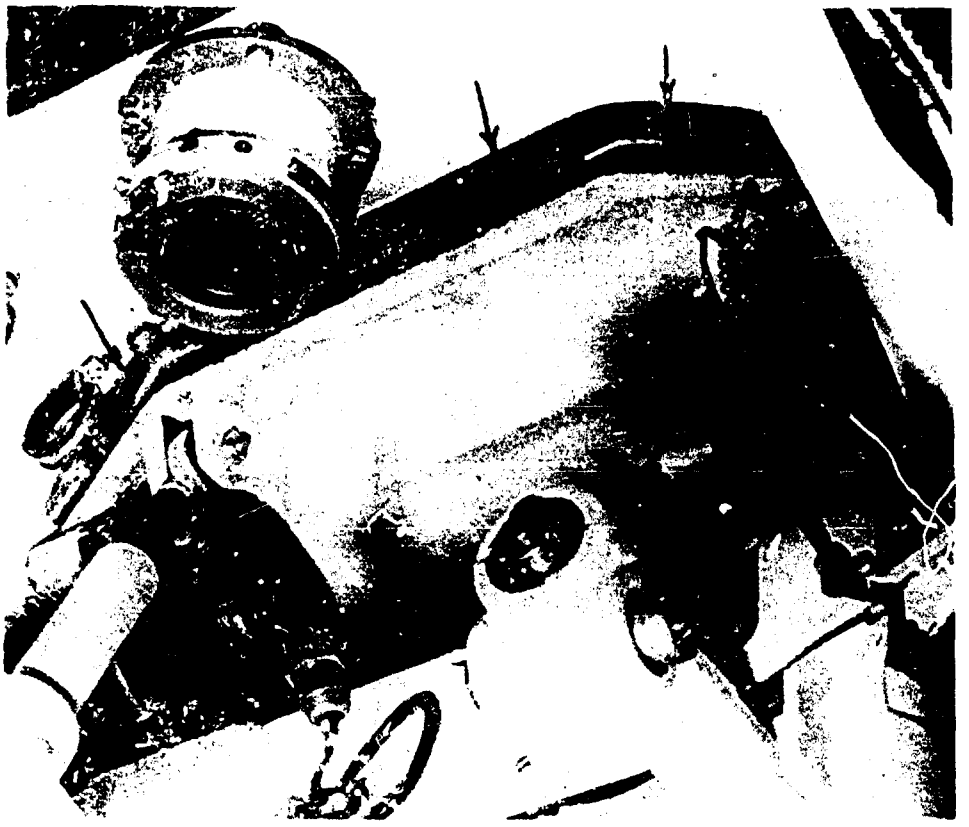

Figure 12. Black Arrows Indicate Splash Guard Installed at Top of MG Cradle and Top of Cupola.

also bent. No fragmentation on the interior of the cupola was noted from two succeeding rounds impacting on the edge of the cupola ring (Figure 13).

The detailed test data for Phase II are contained in Appendix J.

3.2.10 Stage II. Phase III. The third phase of testing consisted of attempts to immobilize the elevating and depressing action of the MG cradle and the traversing operation of the cupola by impact of small-arms projectiles at critical points.

The MG mantlet was subjected to a direct flank attack using the caliber .30, AP, M2 projectile. One round impacted 3/8 inch below the frame and scooped into the side of the cradle. The second projectile impacted on the forward edge of the frame and also scooped in the side of the cradle. Neither impact resulted in any damage to the elevating and depressing action of the MG cradle. One caliber .30, AP, M2 projectile fired from a 30° flank attack hit in the opening between the MG cradle and the frame member and completely locked the elevating and depressing operations of the cradle.

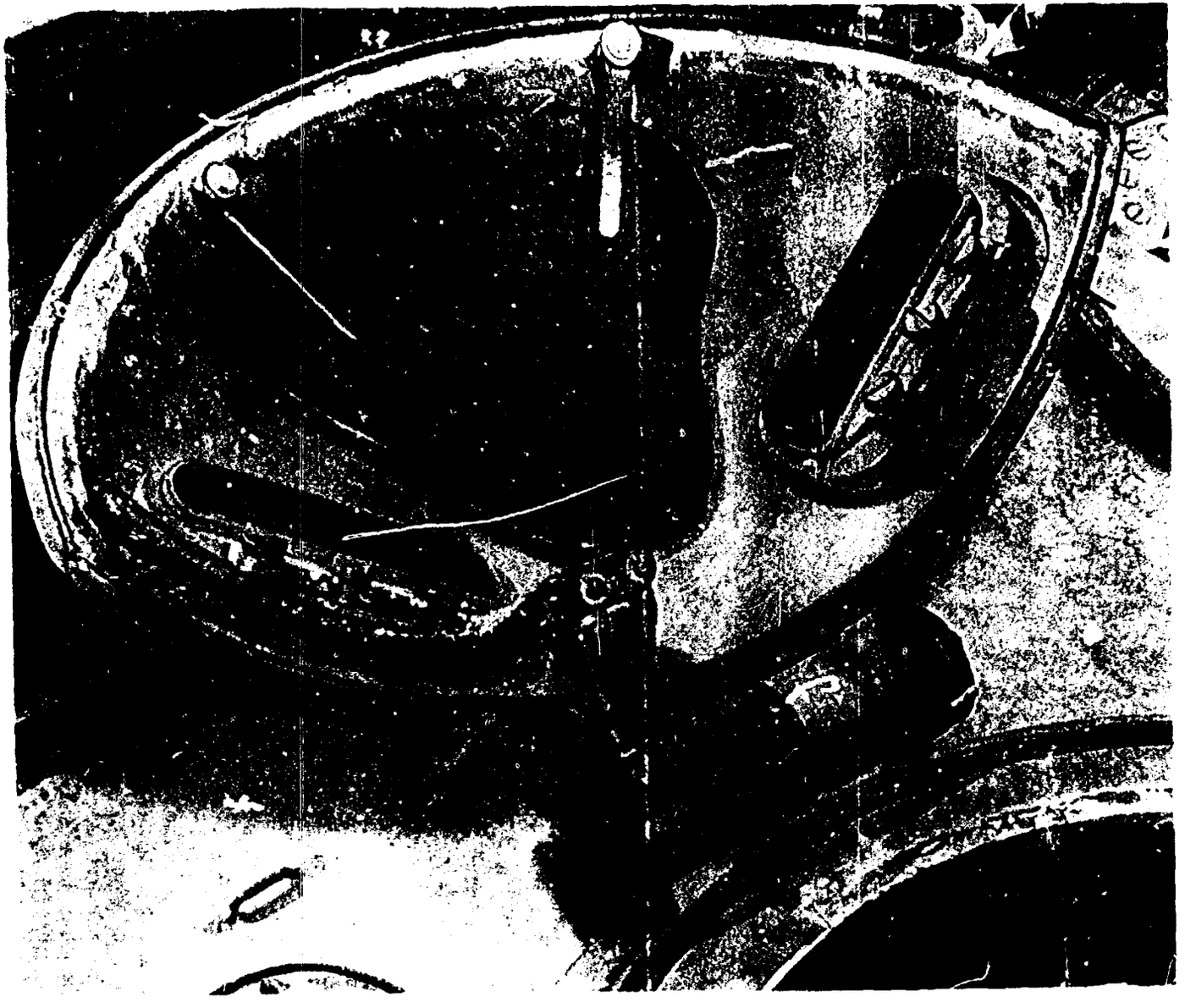

Figure 13: Black Arrows Indicate Splash Guard Installed on Bottom Edge of Cupola Hatch.

The second area to be subjected to an immobilization test was the opening between the cupola and the cupola base ring. Five rounds of caliber .30 AP ammunition were impacted into this opening before the traversing operation of the cupola was prevented. After the first two impacts a grinding noise was heard and manual traverse began to get more difficult. These conditions progressively increased with each succeeding impact until impact number 5 locked the cupola to a $7\frac{1}{2}^{o}$ right traverse and $7\frac{1}{2}^{o}$ left traverse (Figure 14). One other M13 cupola was subjected to the immobilization test of the traversing operation In this case one round of caliber .50 AP ammunition was fired into the opening between the cupola and cupola base ring and completely locked the cupola so that it could not be traversed (Figure 15).

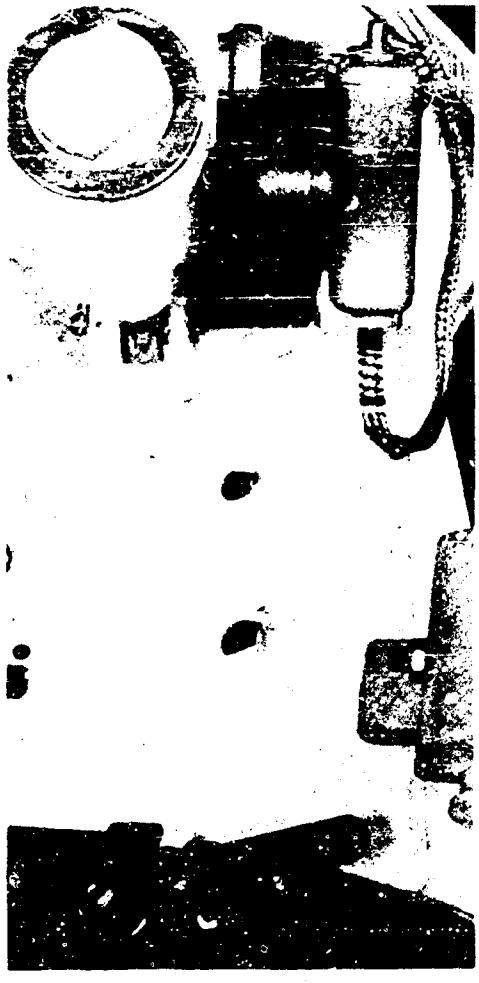

Figure 14 - B32060: Damage to Cupola Mounting Ring and Bearings Resulting From Five Impacts of Caliber .30, AP, M2 Projectiles.

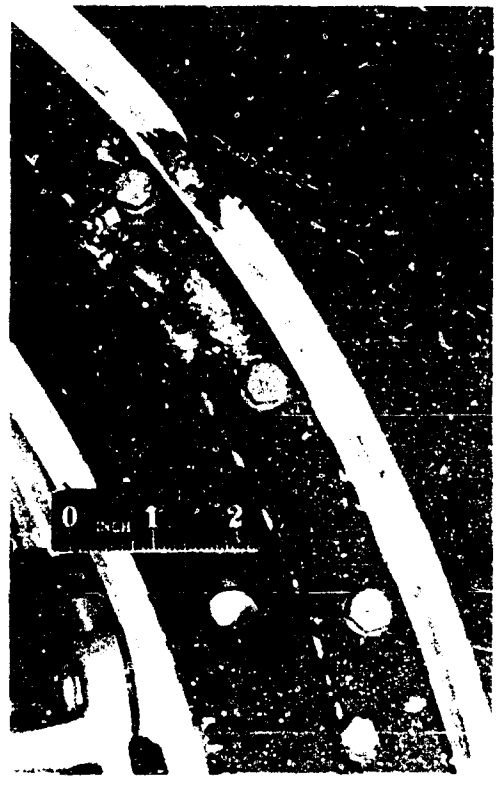

Figure 15 - B32061: Damage to Cupola Mounting Ring and Bearings Caused by One Round of Caliber .50, AP, M2 Ammunition.

The detailed test data for Phase III are contained in Appendix K.

3.2.11 Stage II. Phase IV. The fourth and final phase of testing of the M13 cupola consisted of a resistance-to-penetration test of the cupola armor. This was done in order to determine the level of protection afforded by these cupolas to direct attack by small-arms projectiles. The four areas subjected to attack and the results are outlined as follows:

Projectile	Area Tested	Protection Ballistic Limit, fps	Equivalent Range, yd
Cal .30, AP, M2	Right side - 90° Flank Above vision blocks	No BL(P) obtained Hi PP(P) = 3430	-
Cal .50, AP, M2	Right side - 90° Flank	2463	380
	Above Vision Blocks		
Cal .50, AP, M2	Cupola Roof - 15° overhead	No BL(P) obtained Hi PP(P) = 2864	-
Cal .50, AP, M2	Cupola Hatch - 15° overhead	2382	440

Equivalent range is based on a muzzle velocity of 2935 fps for the caliber .50, AP, M2 projectile.

Round-by-round data for Phase IV are contained in Appendix L.

3.3 Observations

3.3.1 Stage I. The results obtained in Phase I indicate that the opening between the turret and hull is vulnerable to small-arms attack from both direct and overhead fire. The labyrinth ring can be damaged by projectiles of the caliber .50 class and larger, so as to seriously impede the traversing operation, and the 20-mm AP projectile can completely prevent the traversing operation of the turret when this area is subjected to a direct attack. Also the traversing operation can be prevented when the clearance is attacked from the 15° overhead position simulating strafing aircraft fire by both the caliber .60 and 20-mm projectiles. These impacts key the 1/2-inch opening between the turret and hull. It is possible that a heavy flange could be welded to the bottom edge of the turret which would effectively protect this opening against small-arms fire.

The protection afforded against ballistic attack by the M36 driver's periscope, tested in Phase II, was deemed adequate. Although a few glass fragments were displaced from the eye prisms by the 20-mm projectile impacts it was observed that these fragments did not appear to have sufficient

velocity to injure the driver's eyes. The fact should be noted that in the design of future periscopes consideration might be given to discarding the metal case around the sides and rear of the outer prism. It is felt that by this action the possibility of having a damaged periscope jammed in position by petal'ing of the rear metal case would be eliminated and replacement by the driver from within the "buttoned-up" vehicle would be facilitated.

The area around the gun shield opening, tested in Phase III, successfully withstood any keying or locking conditions as a result of small-arms impacts.

The traversing operation of the M1 commander's cupola as reported in Phase IV, withstood attack from the caliber .30 projectiles but suffered partial immobilization from caliber .50 projectile attack. Complete traversing immobilization was encountered from the caliber .60 projectiles penetrating the base of the cupola and bowing the remaining strip so as to press on the turret top. It is thought that a flange welded to the base of the cupola would sufficiently strengthen this area and prevent projectiles of this type from penetrating the base and causing this locking condition.

Due to the extreme vulnerability of the cupola vision blocks, encountered in Phase V, when attacked with small-arms projectiles, it is suggested that serious consideration be given to the adoption of indirect vision devices in the design of future cupolas.

In view of the heavy concentration of fragments from impacting projectiles entering the cupola around the MG mantlet opening on the forward portion of the cupola, it is felt that a nylon splash shield might be installed in the cupola and effectively reduce this hazard to the commander. In the case of the projectile striking between the MG shield and forward edges of the cupola an extension of the gun-shield to the sides would protect this area from projectile impacts. A suggestion is also offered that in the case of the fragment passage to the interior of the cupola at the seam on the bottom edge of the cupola hatch, a correction can be made by the installation of a splash shield on the inside perimeter of the cupola ring.

The results obtained in the resistance-to-penetration tests of the cupola armor covered in Phase VII show the protection afforded by the armor to be adequate against the calibers of projectiles used in the test.

The vulnerability of the clearances on the M48 tank and M1 cupola to bullet splash and immobilization does not seem to be a sigficant factor when the size of each area of clearance is considered individually. The condition does become important for consideration when it is realized that nearly all of the clearance areas are subject to attack at the same time and do present a sizeable target when considered as a unit. The probability of a hit on the clearances, from strafing aircraft or harassing fire from a ground-mounted heavy machine gun

of the Soviet ZPU type, is a factor that must be studied in determining requirements for corrective design.

3.3.2 Stage II. A study of the results obtained from the bullet-splash tests around the MG cradle and hatch cover of the M13 cupolas shows the degree of vulnerability of these areas to small-arms projectiles which strike near openings. The projectiles fracture and follow the contour of cupola components into the cupola itself and may injure or kill the vehicle commander. The fact is readily apparent that the splash shields, especially designed to reduce this hazard, did not measurably add to the level of protection against these fragments. It is felt that possibly a nylon splash shield attached to the interior of the cupola would increase the level of protection to an acceptable degree.

To avoid the keying of the MG cradle in its elevating and depressing action the flange-like shield on the exterior of the MG cradle could be extended to the sides so as to furnish more protection to this area. The immobilization of the cupola with respect to traverse operation, by projectiles hitting in the opening between the cupola and cupola base ring, may be corrected. The installation of a circular deflecting shield around the circumference of the cupola so that it covers the opening completely would deny access to small-arms projectiles.

4. (C) CONCLUSIONS

4.1 Stage I

a. The opening between the turret and hull is vulnerable to small-arms attack from both direct and overhead fire.

b. The M36 driver's periscopes afforded adequate protection against ballistic attack.

c. Small-arms attack directed into the area around the gun shield will not cause immobilization of the gun and gun shield.

d. The traversing operation of the M1 commander's cupola can be partially impaired by caliber .50 attack and completely immobilized when attacked with caliber .60 API projectiles.

e. The cupola vision blocks are extremely vulnerable to ballictic attack with small-arms ammunition.

f. The openings around the machine gun mantlet of the M1 cupola are extremely vulnerable to bullet splash and keying from small-arms projectile impacts.

4.2 Stage II

a. The areas around the machine gun mantlet and hatch cover of the M13 commander's cupola are extremely vulnerable to the passage of bullet splash.

b. The additional metal splash shields installed in the M13 cupola did not measurably increase the protection against bullet splash.

c. The elevating, depressing and traversing operations of the M13 cupola are subject to immobilization by attack with small-arms projectiles.

d. A visual inspection of the vision blocks in the M13 cupola shows their obliquity is less than the vision blocks of the M1 cupola and therefore the M13 cupola vision blocks may be expected to be more vulnerable to small-arms fire from the ground.

5. (C) RECOMMENDATIONS

5.1 Stage I

It is recommended that:

a. The 1/2-inch opening between the turret and hull of the M48 tank be protected from small-arms fire by the addition of a heavy armor flange welded to the bottom edge of the turret.

b. The metal casing around the objective prism of the M36 driver's periscopes be eliminated.

c. A flange be welded to the base of the M1 commander's cupola to prevent locking of the traversing operation when attacked with small-arms fire.

d. Due to the extreme vulnerability of the vision blocks of the M1 cupola when attacked with small-arms projectiles, serious consideration be given to the adoption of indirect vision devices in the design of future cupolas.

e. A nylon splash shield be installed on the interior of the M1 cupola around the openings of the machine gun mantlet to trap the lethal fragment spray encountered in this area.

f. An extension be made to the "ears" on the flanges in the sides of the machine gun mantlet to prevent small-arms projectiles from impacting in the area between the machine gun shield and the forward edges of the M1 cupola and thus locking the mantlet in elevation and depression.

g. A splash shield be installed on the inside perimeter of the cupola ring to prevent passage of bullet splash from small-arms projectiles impacting on the bottom edge of the M1 cupola hatch.

5.2 Stage II

It is recommended that:

a. A nylon splash shield be installed on the interior of the M13 cupola around the machine gun mantlet to trap the lethal fragment spray encountered in this area.

b. Metal splash shields be installed around the hatch cover of the M13 cupola to deny entrance into the cupola of bullet splash resulting from impacting small-arms projectiles.

c. An extension be made of the "ears" on flanges on the sides of the machine gun mantlet to prevent small-arms projectiles from impacting in the area between the machine gun shield and the forward edge of the M13 cupola frame and thus locking the mantlet in elevation and depression.

d. The small opening between the M13 cupola body and cupola base be protected from small-arms fire by the addition of a circular deflecting shield welded to the circumference of the cupola body.

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APPENDICES

APPENDIX A

Correspondence

INDUSTRIAL DIVISION
INDUSTRIAL ENGINEERING BRANCH

TEST DIRECTIVE NO: IT 5098
DATE: 13 Feb 58

Project: Vulnerability Evaluation M48 Tank and Cupolas M-1 and M-13.

Objective: To determine keying resistance of turret hull and gun shield turret clearances, splash resistance of cupola clearances, and penetration resistance of cupola armor from attack by U. S. weapons most representative of the 7.62mm, 14.5mm, 23mm and 37mm USSR types.

Background: In 1957 the United States Armor Board conducted some ballistic tests on the M48 tank. The results of their testing indicated that certain areas of the vehicle, i.e., gun shield, cupola, turret rings and vision devices, were susceptible to damage by small arms fire. This subsequently raised the question of actual vulnerability against such ground weapons as the Soviet 7.62mm rifle and the Soviet 14.5mm anti-aircraft machine gun and such aircraft weapons as the 23mm and 37mm automatic cannon. Similar vulnerability information has been solicited regarding the M-13 light cupola.

Ballistic tests to determine resistance to penetration of roof and cupola armor from 23mm and 37mm aircraft fire will not be required. Similarity of armor design will permit the use of test data obtained from testing the M47 vehicle. The results of this testing are reported in APG Firing Records P-59793, P-61112, and P-61716.

The following program shall be conducted to ballistically evaluate the questionable items and areas against American weapons most representative of the USSR types indicated above.

Item Description:

a. M48A1 Tank (Registration No. 9A943) with commander's cupola M-1.

b. Two (2) extra commander's cupolas (M-1) (Without M.G.).

c. Three (3) M13 Cupolas and test stand. (Without M.G.).

1. Preparation for Test:

a. Turret telescopes and range finders should be removed. Telescopes however should be simulated.

b. Cupola machine guns will be simulated.

c. When deemed necessary witness material shall be utilized to facilitate damage assessment.

2. Description of Test:

a. Hull (M48)

(1) Vision Blocks (Driver)

(a) Weapons & Conditions of Test

1. 20mm AP M95 at 15° above horiz. - normal to block at M. V.

2. Cal. .30 AP M2 at 0° above horiz. - normal to block at M. V.

3. Cal. .50 AP M2 at 0° above horiz. - normal to block at M. V.

(b) Test Objective

1. 20mm phase - block shearing, residual damage.

2. Cal. .30 phase - Res. to penetration, residual damage.

3. Cal. .50 phase - Res. to penetration, residual damage.

b. Turret (M48)

(1) Gun Shield

(a) Weapons & Conditions of Test

1. 20mm AP M95 at 30° above horiz. - at M. V.

a. Direct frontal

b. Direct Flank

(b) Test Objectives

1. Susceptibility to immobilization

(2) Turret Ring

(a) Weapons & Conditions of Test*

1. Cal. 30 AP M2 at 0° - at M. V.
2. Cal. 50 Ball M2 at 0° - at M.V.
3. Cal. 60 AP at 0° - at M. V.

A number of these firings will be attempted through fender boxes.

(b) Test Objectives

1. Susceptibility to immobilization and influence of external objects to decrease hit probability.

c. M1 Commander's Cupola (M48)

(1) Vision Blocks **

(a) Weapons & Conditions of Test

1. Cal. 50 AP M2 - 30° above horiz. - normal to block - at M. V.

(b) Test Objective

1. Resistance to penetration - residual damage.

(2) Cupola Armor **

(a) Weapons and Conditions of Test

1. Cal. 50 AP or 20mm - 30° above horiz. and 0°

a. Direct frontal

b. Direct flank

c. Direct rear

d. Roof (30° above horiz. only)

* Subsequent testing with the larger caliber projectile will be discontinued should immobilization occur with the smaller caliber projectile.

** Testing shall be conducted with cupola off vehicle.

(b) Test Objective

1. Ballistic limit (protection)

(3) Cupola Ring

(a) Weapons & Conditions of Test *

1. Cal. 30 AP M2 at 0° - at M. V.

2. Cal. 50 AP M2 at 0° - at M. V.

3. Cal. 60 AP at 0° - at M. V.

(b) Test Objective

1. Susceptibility to immobilization

(4) Cupola Openings

(a) Weapons and Conditions of Test

1. Cal. 30 Ball M2 at M. V.

a. Hatch clearance on roof

b. Machine gun openings

(b) Test Objectives

1. Susceptibility to bullet splash.

d. M13 Commander's Cupola

(1) Cupola Armor

(a) Weapons and Conditions of Test

1. Cal. 30 AP M2 - 30° above horiz. and 0°

a. Direct flank

b. Roof (30° above horiz. only)

* Subsequent testing with the larger caliber projectile will be discontinued should immobilization occur with the small caliber projectile.

2. Cal. 50 AP M2 - 30° above hor. and 0°

a. Direct flank

b. Roof (30° above horiz. only)

(b) Test Objective

1. Ballistic limit (protection)

(2) Cupola Ring

(a) Weapons and Conditions of Test

1. Cal. 30 AP M2 at 0° - at M. V.

(b) Test Objective

1. Susceptibility to immobilization

(3) Cupola Openings

(a) Weapons and Conditions of Test

1. Cal. 30 Ball M2 at M. V.

a. Hatch clearance on roof

b. Machine gun openings

(b) Test Objectives

1. Susceptibility to Bullet Splash.

3. Photographic Coverage:

Photographs will be taken of those test conditions and results considered necessary for clarity to represent the damage incurred on the item tested. Unique damage results shall also be photographed.

4. Reports:

One formal report will be required. In addition to the basic distribution established by the Industrial Engineering Branch, Industrial Division, OTAC, the following are required:

Headquarters, OTAC, Detroit Arsenal
Center Line, Michigan
Attention: ORDMC-II.60 - 1 copy
Attention: ORDMC-RM.1 - 1 copy

5. Agencies Involved:

a. Ordnance Tank Automotive Command
Industrial Division
Industrial Engineering Branch
Materials Section

b. Aberdeen Proving Ground
Development and Proof Services
Automotive Division
Armor Branch

6. Item Availability: One (1) M48A1 tank, Registration No. 9A943 available at Armor Branch, Automotive Division, APG, with one (1) M-1 cupola. Two (2) additional M-1 cupolas complete with vision blocks will be available to arrive APG by March 5, 1958. Three (3) M-13 cupolas complete with vision blocks and test stand will be shipped to arrive at APG by March 20, 1958.

7. Desired Completion Date: It is desired that M48 vehicle and M-1 cupola testing be completed by March 15, 1958 and M-13 cupola testing be completed by March 28, 1958. Preparation and distribution of final report is requested on or before 1 June 1958.

8. Disposition of Items: Upon completion of testing, all cupolas may be disposed of in accordance with existing regulations. Vehicle may or may not be subject to repair. Disposition will be made on completion of tests.

NOTE: Dates indicated under par. 6 and 7 are subject to change dependent upon approval and release of needed items including test priorities from higher authority

APPENDIX B

8 Apr 58

Detailed Test Data

TRACK I. HEAD NO. 1

M48 Turret Ring - Immobilization

(Firing into 1/2" wide opening between Turret & Hull)

Rd. No.	Projectile Cal .30 AP M2
1	Hit between turret and hull - no damage to traversing operation
2	Disregard
3	Hit between turret and hull - slight extra pressure needed to manually override small catch in left traverse
4	Disregard
5	Hit between turret and hull - no damage to traversing operation
6	Hit between turret and hull - no damage to traversing operation
7	Disregard
8	Disregard
9	Disregard
10	Projectile glanced off lower edge of turret and entered ring area - no damage to traversing operation.
	Cal .50 Ball M2
1	Disregard
2	Disregard
3	Hit between turret and hull - locked turret to lift hand traverse - the small tack welded dust ring on the hull measuring 5/16" high x 3/16" thick was sheared by this impact and a section of the dust ring 3-1/4" in length was petalled into the turret dust ring with sufficient force so as to forestall left handed movement of the turret. Necessary to pull turret from the vehicle to relieve this condition.

Inc. 1

Rd. No.	Cal .60 API T39
1	Hit between turret and hull - slight extra pressure needed to manually traverse to the left on initial try. Very easily overrod, and no extra effort needed after initial effort was needed.
2	Disregard
3	Disregard - Hit 1¼" below hull mounting ring. Scooped up into flat portion of hull mounting ring with one-quarter inch high petals - No damage to traversing operation.
4	Disregard - Hit 3/4" above bottom edge of turret ring with three-eighths inch bulge. Turret completely locked to left traverse when the two damaged areas of rounds 3 & 4 are brought into contact. This condition was completely relived in 5 minutes by use of a cold chisel to relieve the petalled areas.
5	Hit between the turret and hull. A 4" section of the hull dust ring was wedged into the turret ring in such a manner as to permit a 34° right traverse and a 270° left traverse. Turret had to be pulled from the vehicle to relieve this condition.

15° Overhead Attack

Cal .60 API T39
Impacts on Bottom Edge of Turret

Rd. No.	
1	Hit on bottom edge of turret - no hinderance to traversing operation
2	Hit 3/8" above bottom edge of turret. Bowed bottom edge of turret downward closing 1/2" opening and completely locking all traverse operation of turret. 10 minutes labor with cutting torch required to free turret.
3	Disregard
4	Hit 1" above bottom edge of turret. Bowed turret dust ring downward slightly. No hinderance to turret operation.
5	Hit 5/8" above bottom edge of turret. Bowed bottom edge of turret downward and closing 1/2" opening and completely locking all traverse operation. 10 minutes labor with cutting torch required to free turret.
6	Hit 3/4" above bottom edge of turret. Locked turret in left traverse at point of impact. 10 minutes labor with cutting torch required to free turret.

Impact on Machined Edge of Hull

Rd. No.	
1	Hit on ledge on hull and scooped in between hull and turret. Bent hull dust ring into hook shape jamming turret in left traverse. Approximately 3 hours required to pull turret, cut off dust ring and reassemble turret to hull.

15° Overhead Attack

20-MM AP M95
Impacts on bottom edge of turret

Rd. No.	
1	Hit 3/8" above bottom edge of turret. No hinderance to traversing operation.
2	Hit 1/2" above bottom edge of turret. Projectile penetrated turret with nose keyed in hull. Locked turret to traversing operation. 4 hours required to pull turret, remove keying condition and reassemble turret to hull.

NOTE: All shooting in this area was stopped due to the deteriorated condition of the hull dust ring.

90° Flank Attack - Left Side

20-mmAP M95
Impact through Fender tool box into Turret and Hull opening

1	Hit 49-1/4" from front edge and 2" below top edge of box. Projectile penetrated box and hit 1" below opening between turret and hull. Projectile scooped up into base of turret closing the 1/2" opening and locking the turret in traverse operation. 15 minutes labor with cutting torch required to free the turret.

15 April 1958

APPENDIX C

Detailed Firing Data
Stage I.
Phase II

Drivers Periscopes M36(T36)

0° Obliquity-Normal to the glass

Cal .30 AP M2

Round No. 1 - Hit 1¼" right of center and 1-3/8" below top edge - 50% visibility destroyed - no glass displaced from eye prism

Round No. 2 - Hit 5/8" right of center and 1-13/16" below top edge - 85% visibility destroyed - Maximum length of cracking in plastic body 3-3/8" - Eye prism cracked but no glass displaced.

16 April 1958

Cal .50 AP M2

Round No. 1 - Hit 1/8" left of center and 1-5/8" below top edge. Displaced periscope hatch cover - 100% destruction of visibility - Sheared plastic body in half. Eye prism badly cracked but no glass displaced.

Round No. 2 - Hit hull and glanced through periscope 1/8" left of center and 2" below top edge - comp. ely sheared plastic body with 100% destruction of visibility - Eye prism badly cracked but no glass displaced.

Round No. 3 - Hit 7/8" right of center and 1-1/8" below top edge - 75% visibility destroyed - 2" x 2-5/8" opening on back of metal frame - maximum cracking = 2 2-1/2" irregular crack on right side - eye prism cracked but no glass displaced.

Note: This periscope could not be replaced by the driver from within the vehicle due to petalling of metal case surrounding top prism.

Round No. 4 - Hit 1/8" left of center and 1-1/2" below top edge - opening of 4" on metal case - sheared plastic body - displaced top portion of periscope - 100% destruction of visibility - eye prism cracked but no glass displaced.

Incl 2

17 April 1958

15° Overhead Attack

Normal to the glass

20mm AP M95

Round No. 1 - Hit in center of and 1-1/4" below top edge - 100% destruction of visibility - shattered plastic body down to eye prism - Displaced top prism - Very fine fragments inside tank. Two irregularly shaped pieces of glass displaced from eye prism measuring 15/16" x 1/2" and 7/16" x 1/8".

Round No. 2 - Hit 1/8" left of center and 1" below top edge - 100% destruction of visibility - displaced top prism - shattered plastic body - small amount of glass dust entered drivers compartment. Small piece of glass measuring 3/8" x 1/8" displaced from eye prism. Projectile penetrated top prism causing a 7/8" x 3" scoop in the armor behind the prism and locking the drivers escape hatch shut. Twenty minutes labor by two men using cold chisels, hammers and wrecking bars were needed to free the driver's hatch.

DS202.1E

APPENDIX D 18 April 1958

Detailed Firing Data
Stage I.
Phase III

M48 Gun Shield

Direct Flank Attack-Right Side

15° Overhead Attack

20-mm AP M95

Round No. 1 - Hit between turret and gun shield - Gun at C° elevation - Entrance diameter 3/4" x 1" - Projectile fractured - part in plate - 1/2" high petalling - no damage to elevating operation

Round No. 2 - Hit between turret and gun shield - Gun at 0° elevation Entrance diameter 1" x 1" - Projectile fractured - part in plate - no measurable petalling - do damage to elevating operation.

Round No. 3 - Hit between turret and gun shield - Gun at 0° elevation - Entrance diameter 7/8" x 1" - Projectile penetrated gun shield and passed into Co-AX scope tube - this round would have destroyed scope - no damage to elevating operation.

Round No. 4 - Hit between turret and gun shield - Gun at 0° elevation - Entrance diameter 1 3/4" x 1" - Projectile fractured - part in plate - no damage to elevating operation.

Top of Gun shield
Direct Flank Attack
15° Overhead Attack
20-mm AP M95

Round No. 1 - Disregard

Round No. 2 - Disregard

Incl 3

APPENDIX E

21 April 1958

Detailed Test Data
Siege
HEMTT IV

M1 Cupola

Immobilization of Cupola Ring

45° Overhead Attack

Cal .50 AP M2

Round No. 1 - Hit at base of cupola - no damage to traversing operation

Round No. 2 - Hit at base of cupola - no damage to traversing operation

Round No. 3 - Disregard

Round No. 4 - Disregard

Round No. 5 - Hit at base of cupola - no damage to traversing operation

Round No. 6 - Hit at base of cupola - no damage to traversing operation

Cal .50 AP M2

Round No. 1 - Disregard

Round No. 2 - Disregard

Round No. 3 - Hit at base of cupola - Projectile penetrated through base, fractured and stuck in mounting ring on turret top. Cupola could be traversed to the right until it met this stuck projectile. Cupola could not be traversed to the left past this piece of projectile. One hour was required to pull the cupola and clear race ring using a hammer, and cold-chisel.

Round No. 4 - Hit at base of cupola - no damage to traversing operation

Round No. 5 - Hit at base of cupola - no damage to traversing operation

Round No. 6 - Hit at base of cupola - no damage to traversing operation

22 April 1958

Cal .60 API T59

Round No. 1 - [illegible] 3/4" above base of cupola - cupola completely locked in position - 1-7/8" section of dust ring displaced from cupola and lodged against ring or turret roof - retaining ring or underside of cupola bowed 3/4" downward. Cupola was pulled from turret, bowed and damaged area flame cut from cupola, and cupola replaced and operating satisfactorily in one hour.

2.2.4

Cal .60 API T39

Round No. 2 - Hit 7/8" above base of cupola - completely looked cupola in traverse - a bow with a length of 4 inches along the cordline 3/4" deep resulted from th s impact. No effort was made to repair cupola.

APPENDIX F

Detailed test with [illegible]. 23 April 1958

Phase V

M1 Commander's Cupola

15° Overhead Attack

Cal .50 AP M2

Round No. 1 - Hit 3-3/4" from left edge and 1-1/8" below top edge - Projectile penetrated block - five large irregularly shaped pieces of glass measuring 3" x 1-1/4"; 4" x 1-1/2"; 2-1/2" x 1"; 2" x 1-1/2"; 2" x 7/8" displaced from rear. Numerous pin hole penetrations in cardboard back-up material.

Round No. 2 - Hit 3-1/2" from left edge and 1-1/2" below top edge - Projectile stuck in top of vision block frame - large piece of glass 4" x 1-7/8" displaced from rear - most of glass retained by mastic layers in metal case - no fragments penetrated cardboard back-up material.

Cal .50 Ball M2

Round No. 1 - Hit 4" from left edge and 1-1/4" below top edge - Projectile jacket stripped from cove - cove penetrated vision block - part of jacket retained in glass - three large pieces of glass displaced from rear measuring 5-1/2" x 1-7/8"; 3-7/8" x 1-7/8"; 3-7/8" x 1-7/8" - numerous fine glass fragments displaced.

Cal .50 AP M2 (reduced charges estimated M.V. 2500 fps)

w/o Shield

Round No. 1 - Hit 4-1/8" from left edge and 1-1/2" below top edge. Projectile lodged in block. Two large fragments 4" x 1-7/8" displaced from rear with numerous small fragments and powdered glass.

w/Shield

Round No. 2 - Hit 9" from left edge and 1-1/4" below top edge. Projectile penetrated block - four large fragments measuring 4-1/2" x 1-7/8"; 3-1/2" x 1-7/8"; 3-3/4" x 1-7/8" and 2-3/4" x 1-7/8" displaced from rear - cardboard penetrated by fragments - shield destroyed.

Part C 5

24 April 1958

Cal .30 AP M2 w/o Shield

Round No. 1 - Hit 4" from left edge and 1-5/8" from top edge
Projectile scooped with top edge of face mounting ring - displaced a few fine glass fragments from rear of block.

Cal .30 AP M2 w/Shield

Round No. 2 - Hit 3-7/8" from left edge and 1-1/4" below top edge.
Projectile scooped into top edge of face mounting ring - displaced a few fine glass fragments from rear of block - no fragments passed experimental shield in rear of block.

Cal .50 AP M2

0° Attack

w/Shield

Round No. 1 - Disregard

Round No. 2 - Disregard

Round No. 3 - Hit 4" from left edge and 1" below top edge -
Projectile did not penetrate block - numerous small fragments displaced from rear of block - shield contained all fragments.

25 April 1958

w/o Shield

Round No. 4 - Hit 4-1/4" from left edge and 1" below top edge -
Projectile did not penetrate block - numerous small fragments displaced from rear of block.

DS702BP

APPENDIX G

DETAILED TEST DATA
Stage 1.
PHASE VI

M1 Cupola

Splash Around Machine Gun Opening

Direct Frontal Attack

Cal .30 Ball M2

25 April 1958

Round No. 1 - Disregard

Round No. 2 - Disregard

Round No. 3 - Disregard

Round No. 4 - Hit on forward edge of machine gun barrel support tube on right side of gun - concentrated blast pattern tore Kraft paper 7" in direct line with point of impact - one 1/2" - one 3/4" and 34 L 1/8" holes in paper from fragments.

Round No. 5 - Hit on forward edge of machine gun barrel support tube on right side of gun - one 1" and one 1/2" hole + 57 L 1/8" pin holes from fragments counted on paper. Projectile hit locking strap on machine gun ballistic ring, shearing strap and bending ballistic ring out of line.

Opening Between MG Mantlet & Cupola Front

Direct Flank Attack - Left Side

Round No. 1 - Disregard

Round No. 2 - Hit in opening between MG mantlet and forward edge of cupola - Locked MG completely in elevation and depression operation. 15 minutes required to free keying condition using hammers and cold chisels.

Shot 6

NS70288

Opening Between Bottom Edge of MG Mantlet and Cupola Bottom

MG in Maximum Elevation

Direct Frontal Attack

Cal .30 Ball M2

Round No. 1 - Hit in opening on under side of MG mantlet and cupola bottom - completely shredded Kraft paper placed behind opening.

Round No. 2 - Hit in opening on under side of MG mantlet and cupola bottom - completely destroyed Kraft paper placed behind opening.

Round No. 3 - Disregard

Round No. 4 - Hit in opening on under side of MG mantlet and cupola bottom - completely destroyed Kraft paper placed behind opening.

Splash Test Around Hatch Cover Seam

90° Flank Attack - Left Side

Cal .30 Ball M2

Round No. 1 - Hit 10-5/8" above bottom edge - no splash in cupola

Round No. 2 - Disregard

Round No. 3 - Disregard

Round No. 4 - Hit 8-1/8" above bottom edge - no splash in cupola

Round No. 5 - Hit 7-1/2" above bottom edge - no splash in cupola.

Splash Test at Seam at Bottom of Hatch Cover

Cal .30 Ball M2

Round No. 1 - Hit 1-1/8" right of left edge of hatch on bottom edge - 5/8" hole in fragment ring on base of cupola - two 3/4" - one 3/8" - four L 1/4" fragment holes in Kraft paper - cut rubber seal.

Round No. 2 - Hit 1-3/4" right of left edge of hatch on bottom edge - Displaced bottom portion of rubber ring - one 1/4" - 62 L 1/8" fragment holes in Kraft paper..

STAGE I.
PHASE VII

BALLISTIC TESTS OF ARMOR

M1 Cupola No. 86
DETAILED DATA

PROJECT NO. JT-5098 DATE OF TEST 30 April 1952

PLATE NO. _____ HEAT NO. _____ NOMINAL THICKNESS _____ ACTUAL THICKNESS (AVG) _____

BRINELL HARDNESS _____ CHARPY IMPACT AT -40 F _____ FT LBS

PROJECTILE Caliber .50 AP M2 PLATE OBLIQUITY 35°

Machine Gun Mantlet - Direct Frontal Attack - 15° Overhead Firing

RD NO	STRIKING VELOCITY	PENETRATION	RESULT - ARMOR	RESULT - PROJECTILE
1	Lost	PP(p)	Face - Scoop 1¾" x ½" Rear - No bulge	Shattered
2	Lost	PP(p)	Face - Scoop - 5/8" x 1/2" - 7/8" Crack - Rear - No bulge	PIP
3	2797	PP(p)	Face - Scoop - 2¼" x ½" Rear - No bulge	Shattered
*4	2870	PP(p)	Face - Scoop 1½" x 5/8" - Two cracks 7/8" x 1" Rear - No bulge	Shattered
*	No protection Ballistic Limit obtained - High PP(p) = 2870 fps			
			Direct Flank Attack 15° Overhead Firing - Right Side - 42° Obl.	
1	2853	PP(p)	Face - Scoop 1-7/8"x7/8" - Rear - No bulge	Shattered
	* No protection Ballistic Limit obtained - High PP(p) = 2853 fps.			
			Direct Flank Attack 15° Overhead Firing - Right Side - 42° Obl. 20mm AP M95	
1	2366	PP(p)	Face - Scoop 1-3/8"x7/8"x5/8" Rear - Slight bulge - no cracking.	Shattered

Encl 7

ARMY - ABERDEEN PROVING GROUND MD 7-20

ORDNL - 1216 - Sept 51

PHASE VII

BALLISTIC TESTS OF ARMOR
M1 Cupola No. 88
DETAILED DATA

PROJECT NO. IT-[illegible] DATE OF TEST 30 April 1958

PLATE NO. _____ HEAT NO. _____ NOMINAL THICKNESS _____ ACTUAL THICKNESS (AVG) _____

BRINELL HARDNESS _____ CHARPY IMPACT AT -40 F _____ FT LBS

PROJECTILE Caliber .50 AP M2 PLATE OBLIQUITY 35°

Machine Gun Mantlet - Direct Frontal Attack - 15° Overhead Firing

RD NO	STRIKING VELOCITY	PENETRATION	RESULT - ARMOR	RESULT - PROJECTILE
2	2620	PP(p)	Face - Scoop 2"x2½" Rear - Slight bulge. No cracking.	B - Bu F- NIP
3	2863	PP(p)	Face-Scoop 1-7/8"x1-1/2" Rear - Slight bulge. No cracking.	B - Bu F - NIP
4	2929	PP(p)	Face - Scoop 2" x 1¾" Rear - Slight bulge. No cracking.	Shattered
	• No protection Ballistic Limit obtained - High PP(p) = 2929 fps			
			Hatch Cover - Direct Rear - 15° Overhead Firing 20mm AP M95	
1	2858	PP(p)	Face - Scoop 2-1/8"x1" Rear - Slight bulge - no cracking.	B - Bu F - NIP
2	2841	PP(p)	Face - Scoop 2¼" x 1½" Rear - Slight bulge - No cracking	
	•No protection Ballistic Limit obtained - High PP(p) = 2858 fps.			

ARMY - OS - ABERDEEN PROVING GROUND, MD - T 20

APPENDIX I

DETAILED TEST DATA
M13 - CUPOLAS
STAGE II
PHASE I

Bullet Splash
Cal .50 MG Opening
Direct Frontal Attack
Cal .30 Ball M2

Round No. 1 - Hit 3/8" above MG Barrel support at 11 o'clock
Displaced 1-3/4" x 3/8" piece of external ballistic ring -
No fragments entered cupola.

Round No. 2 - Hit at opening between MG barrel support and external
ballistic ring at 9 o'clock - No fragments in cupola.

Round No. 3 - Disregard

Round No. 4 - Disregard

Round No. 5 - Disregard

Round No. 6 - Disregard

Round No. 7 - Disregard

Round No. 8 - Hit at opening between exterior ballistic ring and MG cradle -
No fragments in cupola.

OPENING AT BOTTOM OF MG CRADLE & CUPOLA RING
MG - MAXIMUM ELEVATION

Round No. 1 - Hit 1" above opening on bottom edge of cradle - Destroyed Kraff paper

HATCH OPENING SEAM - 90° FLANK ATTACK

Round No. 1 - Hit 3-5/8" above bottom and 3/16" right of seam - 2 holes $< 1/2"$
5 holes $< 1/8"$

Round No. 2 - Disregard

Round No. 3 - Disregard

Round No. 4 - Hit 1-1/2" above bottom edge & on seam - 1 hole 3/4"; 3 holes
$< 1/2"$; 4 holes $< 1/4"$; 14 holes $< 1/8"$. Bent 3-3/4" section
of dust shield on hatch.

Round No. 5 - Disregard

Round No. 6 - Disregard

Round No. 7 - Disregard

Incl 1

AD590272

APPENDIX J

Detailed Test Data

PHASE II

Bullet Splash with Special Splash Guards
Cal .30 Ball M2 - Opening at Bottom of Cradle & Cupola Ring
MG-Maximum Elevation-Direct Frontal Attack

Round No. 1 - Hit 3/8" above opening - destroyed Kraft paper

Round No. 2 - Hit directly in opening - destroyed Kraft paper

4 Turns in Depression-under Maximum Elevation

Round No. 3- Hit 1" above opening - 1 hole 5/16"; 1 hone 1/4"; 22 holes <1/16" in Kraft paper.

30° Overhead Attack
Opening between top of MG cradle and Cupola top
MG-Maximum Depression

Round No. 1 - Disregard

Round No. 2 - Hit on top of cradle and glanced into opening - destroyed Kraft paper

Opening at bottom of Cradle & Cupola
w/Aluminum Splash Guard in Place
MG-Maximum Elevation

Round No. 1 - Hit on opening - destroyed Kraft paper - bent aluminum splash guard

Round No. 2 - Hit 1-1/4" above opening - 11 holes <1/8"; 11 holes <1/16" in Kraft paper.

Round No. 3 - Hit 3/4" above opening - destroyed Kraft paper - badly bent aluminum shield.

Opening at Bottom edge of Hatch & Cupola Base
Special Splash Guards & Aluminum Shield

Round No. 1 - Disregard

Round No. 2 - Disregard

Round No. 3 - Hit on opening - 1 hole 1/8"; 30 holes <1/16" in Kraft paper
Bent aluminum splash shield.

Round No. 4 - Hit on edge of ring - No splash in cupola

Round No. 5 - Disregard

Round No. 6 - Hit on edge of ring - No splash in cupola.

NS90-7

Incl 2

APPENDIX K
Detailed Test Data

PHASE III

IMMOBILIZATION
M3 Cradle
Cal. .30 AP M2
90° Flank Attack

Round No. 1 - Disregard

Round No. 2 - Hit 3/8" below frame and scooped into side of cradle - no hinderance to elevating or depressing operation.

Round No. 3 - Hit on forward edge of frame and scooped into side of cradle - no damage to elevating or depressing operation.

30° Flank Attack

Round No. 1 - Hit at opening between cradle and frame - Locked cradle in elevation and depression.

Cupola Base Ring
Hold down bolts tightened to 85 lbs torque
90° Flank Attack-Cal .30 AP M2

Round No. 1 - Hit on base ring - no damage to traverse

Round No. 2 - Hit on base ring - no damage to traverse - grinding noise present when traversing cupola.

Round No. 3 - Hit on base ring - no damage to traverse - increased grinding noise.

Round No. 4 - Hit on base ring - increased grinding noise - cupola harder to traverse.

Round No. 5 - Hit on base ring - manual traverse locked to $7\frac{1}{2}°$ R & $7\frac{1}{2}°$ L.

90° Flank - Cal .50 AP M2

Round No. 1 - Hit on base ring - Locked cupola in position

Dnol 3

APPENDIX L
Detailed Test Data

PHASE IV

Resistance-to-Penetration
Direct Flank - Right Side
Above Vision Blocks - Cal .30 AP M2

Rd. No.	Velocity(fps)	CP/PP	Remarks
1	2535		Disregard
2	2623	PP(P)	No damage
3	3130	PP(P)	Slight bulge on rear
4	3257	PP(P)	Slight bulge on rear
5	3430	PP(P)	Large bulge - Fine hair cracks

No BL(P) obtained - Hi PP(P) = 3430 fps.

Cal .50 AP M2

1	2705		Disregard
2	Lost	CP(P)	ED = 5/8" x 5/8"
3	Lost	-	Disregard
4	2548	CP(P)	ED = 5/8" x 1/2"
5	2257	PP(P)	Large bulge - Punching Started
6	2331	PP(P)	Large bulge - Fine cracking
7	2403		Disregard
8	2401	PP(P)	Large bulge - No cracking
*9	2480	CP(P)	ED = 1/2" x 1/2"
*10	2445	PP(P)	Large bulge - No cracking

*Protection Ballistic Limit = 2463 fps.

Cupola Roof
15° Overhead Attack
Cal .50 AP M2

1	2732	PP(P)	No bulge on rear
2	2791	PP(P)	No bulge on rear
3	2864	PP(P)	No bulge on rear

* No BL(P) obtained - Hi PP(P) = 2864 fps.

Commander's Hatch
15° Overhead Attack
Cal .50 AP M2

1	1929	PP(P)	Medium bulge - No cracks
2	2063	PP(P)	Medium bulge - No cracks
3	Lost	PP(P)	Medium bulge - No cracks
4	Lost	PP(P)	Medium bulge - No cracks
5	2606	CP(P)	ED= 5/8" x 5/8"
6	*2402	CP(P)	ED= 3/8" x 3/8"
7	2336	PP(P)	Medium bulge - No cracks
8	*2362	Pp(P)	Large bulge - Hair cracks

* Protection Ballistic Limit = 2382 fps

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Incl. 4

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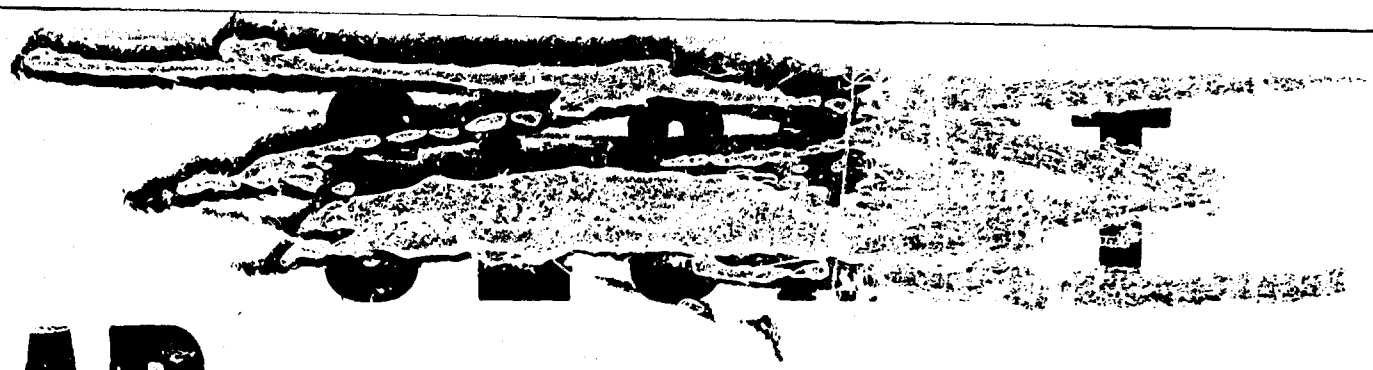

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