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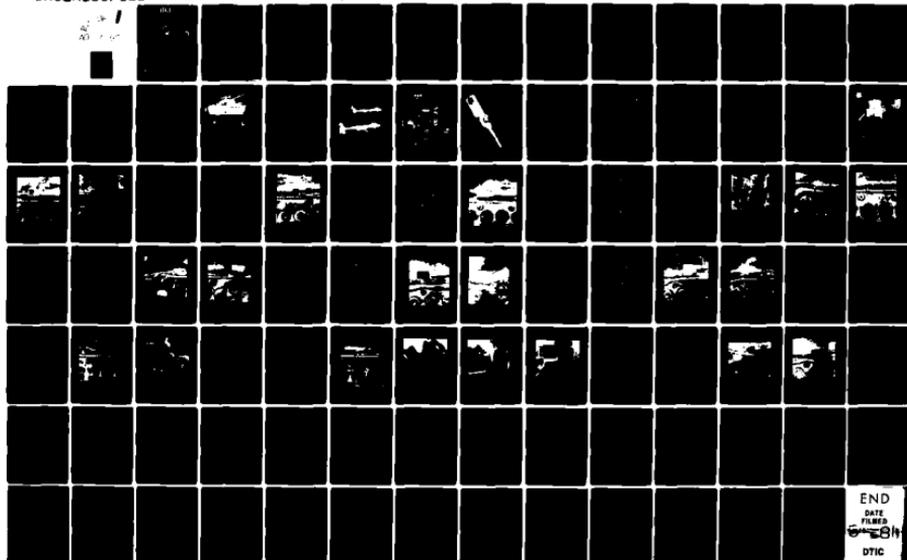
NAVAL POSTGRADUATE SCHOOL MONTEREY CA
COMBAT DAMAGE ASSESSMENT TEAM. A-10/GAU-8 LOW ANGLE FIRINGS VER--ETC(U)
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COMBAT DAMAGE ASSESSMENT TEAM,
A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS
SIMULATED SOVIET TANK COMPANY (ARRAY 20)
(AEROJET LOT NUMBER AJD 79A181-001)
(19 SEPTEMBER 1979)
10 Kussel D.H.S. STOLFI
Raymond B.R. MCEACHIN
11 MAY 1980

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Prepared for: A-10 System Program Office
Wright Patterson Air Force Base
Ohio 45433

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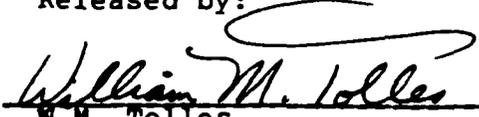
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes firings of the A-10/GAU-8 weapon system on 19 September 1979 against a Soviet tank company simulated by 10 combat loaded M-47 tanks. The pilots making the firing passes attacked at low altitude and used correspondingly low dive angles in order to simulate movement through a hostile air defense system. Ammunition used in the attacks comprised Aerojet Lot Number AJD 79A181-001 30mm armor piercing incendiary (API) rounds, which proved to be effective damage agents against substantial areas of		

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the U. S. M-47 tanks used as targets. The pilots in ten successful firing passes expended a total of 1349 rounds of which 243 impacted the targets. Of the projectiles impacting on target, 42 achieved perforations of the armored envelope. The simulated Soviet tank company was destroyed as a combat formation with seven tanks being totally immobilized immediately. One additional tank would have been immobilized after approximately 500 meters of further movement. Among those eight tanks noted above as immobilized, three suffered catastrophic damage from perforating projectiles which penetrated into the fuel tanks and ignited diesel fuel.

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TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	1
Attack Parameters	1
Weapon Effects	1
Damage Assessment	1
Test Conditions	2
Results	2
BACKGROUND	4
TEST PHILOSOPHY	4
SIMULATED GROUND COMBAT SITUATION	5
TARGET TANKS	7
TEST PERFORMANCE AND RESULTS	7
DAMAGE ASSESSMENT	15
Tank Number 47	16
Tank Number 48	21
Tank Number 4	24
Tank Number 41	27
Tank Number 7	33
Tank Number 27	37
Tank Number 29	41
Tank Number 33	45
Tank Number 31	50
Tank Number 20	56
SUMMARY AND CONCLUSIONS	60
APPENDIX A	62
APPENDIX B	67

LIST OF FIGURES

Figure	Page
1. Russian T-62 Medium Tank	8
2. U.S.A.F./Fairchild Republic A-10 Aircraft	10
3. Fairchild A-10 Series Aircraft	11
4. GAU-8/A-10 30mm Gun System	12
5. 30mm Armor Piercing Incendiary (API) Projectile. . .	13
6. Approximate Target Layout	14
7. Impact Diagram, Tank 47	17
8. Fragment Damage to Commander Manikin from Impacts 7, 8, and 10, Tank 47	18
9. Impact 8, Perforatin of Left Turret, Tank 47	19
10. Damage to Track and Suspension System caused by Impacts 13, 14, 15, 24, and 25; Tank 47	20
11. Impact Diagram, Tank 48	22
12. Perforation 5 Destroyed Oil Cooler Inlet Line from Transmission, Tank 48	23
13. Impact Diagram, Tank 4	25
14. Crew Casualties Resulting from Impacts 3, 4, 5, and 6, Tank 4	26
15. Impact Diagram, Tank 41, Left Side	28
16. Impact Diagram, Tank 41, Rear	29
17. Wounds Sustained by Tank Commander Manikin, Tank 41.	30
18. Damage to Track and Suspension System, Tank 41 . . .	31
19. Jammed Turret caused by Impacts 9, 10, and 11, Tank 41	32

LIST OF FIGURES (CONTINUED)

Figure	Page
20. Impact Diagram, Tank 7	34
21. Damage to Track Connector and Center Guide caused by Impact 9, Tank 7	35
22. Extensive Damage to Track and Suspension System caused by Impacts 25, 26, 27, and 29, Tank 7	36
23. Impact Diagram, Tank 27	38
24. Impacts 7 and 14, Perforations of Left Hull Armor.	39
25. Impacts 19 and 23, Perforations into the Engine Compartment	40
26. Impact Diagram, Tank 29	42
27. Fuel for the Catastrophic Fire was Provided by Impact 20, which Perforated the Left Fuel Tank, Tank 20	43
28. Perforations 2, 4, 8, and 12 which Incapacitated the Crew, Tank 29	44
29. Impact Diagram, Tank 33, Left Side	46
30. Impact Diagram, Tank 33, Front	47
31. Impact 6 which Perforated the Turret and Caused Loader Casualty, Tank 33	48
32. Damage to Loader Manikin (arrow) caused by Impact 6, Tank 33	49
33. Impact Diagram, Tank 31	51
34. Impact 17, Perforation of Hull and Fuel Tank, Target 31	52
35. Damage to Commander Manikin caused by Impact 2, Tank 31	53
36. Damage to Gunner Manikin caused by Impact 2, Tank 31	54

LIST OF FIGURES (CONCLUDED)

Figure	Page
37. Damage to Loader Manikin caused by Impact 2, Tank 31	55
38. Impact Diagram, Tank 20	57
39. Impacts 8 and 9 Penetrated the Fuel Tank Providing Fuel for a Major Fire, Tank 20	58
40. Probable Crew Casualties were caused by Impact 1 which Perforated the Turret, Tank 20	59
A-1. Array 20 Attack Aspect Summary	65

LIST OF TABLES

Tables	Page
I. Array 20 Summary of A-10 Aircraft in Low Angle Gun Attack versus Simulated Soviet Tank Company	3
II. Comparison of Ideal & Practical Test Situations	6
A-I. Array 20 Results Summary	63
A-II. Array 20 Perforation Location Summary	64
A-III. Array 20 Aircraft Attack Parameters	66

COMBAT DAMAGE ASSESSMENT COMMITTEE (CDAC) EXECUTIVE SUMMARY

Under the technical direction of the Combat Damage Assessment Committee (CDAC), the Combat Damage Assessment Team (CDAT) conducted firings of the A-10/GAU-8 weapon system against an array of 10 tanks simulating a Soviet tank company deployed for an attack. The CDAT used M-47 tanks stowed with main gun ammunition, diesel fuel, lubricating oil, and crew manikins to simulate the Soviet tanks. The pilots of the A-10 aircraft used in the firings conducted firings at low altitudes and low dive angles which simulated attack below the altitude of effective engagement for opposing air defense networks employing acquisition and fire control radar. The purpose of the test was to evaluate the effects of the Aerojet 30mm API anti-tank ammunition (lot Number AJD 79A181-001) of the GAU-8 gun under challenging conditions of engagement for the A-10/GAU-8 system against realistically simulated Soviet main battle tanks.

The CDAC assessed the results of the low angle cannon firings of the A-10 aircraft against the simulated Soviet tank company as follows:

1. Attack Parameters: The pilots of the A-10 aircraft attacked the simulated Soviet tank company at low altitude and dive angles. The GAU-8 cannon has a ground selectable nominal fire rate of either 4200 rounds per minute or 2100 rounds per minute. The system was set to fire at the 4200 round per minute rate during this test. The pilots made a total of ten passes, each at a primary target tank. The passes resulted in projectile impacts on ten primary target tanks. The attack open-fire dive angles averaged three degrees for the ten passes against the targets. Open-fire slant ranges averaged 3658 feet. The pilots fired 1349 rounds in ten bursts averaging 135 rounds and 2.01 seconds each.

2. Weapons Effects: The A-10/GAU-8 weapon system achieved 243 impacts on the 10 target tanks. The ratio of direct impacts to total rounds fired was 0.14. Ricochet hits are also capable of causing damage. If the ricochet hits are added to the direct impacts, the overall ratio of impacts to rounds fired becomes 0.18. The weapon system achieved 42 perforations of the armored envelopes of the tanks with a ratio of perforations to direct impacts of 0.22. The ratio of perforations to total impacts is 0.17. Many projectiles, which did not perforate armor, severely damaged exterior track and suspension components of the tanks as well as command and control optical devices and gun tubes.

3. Damage Assessment: The attacking A-10/GAU-8 weapon system inflicted three catastrophic kills on tanks in the company array. Five other tanks were immobilized, of which two were degraded in firepower and two others completely deprived of the use of main armament. One additional tank was seriously degraded in mobility and firepower. Only one tank retained a significant combat capability. The simulated Soviet Tank company was judged to have been destroyed, since all except one tank was severely

damaged, preventing activity as a formation.

4. Test Conditions: The target tanks were sited in open, flat desert terrain with no cover and little concealment. Aerial weather conditions were ones of unlimited ceiling and visibility. Shortly after the initial firing, clouds of white dust from projectile impacts were evident. Such conditions effectively simulated the actual obscuration which would have been presented to the pilots in combat.

5. Results: The overall results of the test are summarized in Table I. Appendix A contains graphical and summary information for this firing and Appendix B contains definitions of the terms used in this publication.

TABLE 1. Array 20 Summary of A-10 Aircraft in Low Angle Gun Attack versus Simulated Soviet Tank Company (19 September 1979)

Tank No.	A-10 Primary Pass*	A-10 Speed (fps)	A-10 Approach		A-10 Attack		Gun Effects		Damage			Tank Immob	Attack Aspect (degrees)
			Alt (ft)	Open Fire Range** (ft)	Dive Angle (degrees)	Perfs (each)	Impacts (each)	M %	F %	K %			
47	1/1	573	313	3173	-1.0	92	25	3	100	100	---	Yes	274
48	1/2	537	243	3684	-2.0	129	9	3	100	---	---	Yes	273
4	1/3	532	363	3816	-2.0	137	24	5	90	95	---	NO	275
41	1/4	540	353	3023	-3.0	126	40	4	100	100	---	Yes	274
7	1/5	532	388	4127	-3.0	258	31	3	***100	20	---	Yes	272
27	2/1	583	453	3392	-2.0	70	24	8	---	---	100	Yes	272
29	2/2	539	563	3883	-5.0	126	28	5	---	---	100	Yes	264
33	2/3	503	513	3654	-5.0	113	28	5	10	30	---	NO	257
31	2/4	535	613	3948	-5.0	137	22	2	100	95	---	Yes	263
20	2/5	534	463	3883	-5.0	161	12	4	---	---	100	Yes	260
Applicable													
Totals:													
Averages:													
		540	427	3658	-3.3	1349	243	42	3	K-Kills	8	Left	
						134.9	2.43	4.2	2	M- and F-Kills		Side	
									3	M-Kills			
									1	High & M and F Degradation			
									1	Light M and F			

*Key: 1/2 means pilot 1, pass 1; 2/3 means pilot 2, pass 3; etc.
 **Derived from HUD film
 ***Interdiction type M-Kill after 500 meters

BACKGROUND

Since February, 1978, the Armament Directorate, A-10 System Program Office, Wright Patterson Air Force Base, Ohio, has conducted firing tests using the A-10/GAU-8 system in low-level, air-to-ground engagements of armored targets. The tests have been conducted within the framework of the GAU-8 30mm ammunition Lot Acceptance Verification Program (LAVP) - Airborne. The LAVP has the following objectives which apply to the present tests:

- A. To evaluate the performance of existing production lots of GAU-8 ammunition when fired from the air under operational conditions.
- B. To evaluate the lethality of GAU-8 ammunition against armored targets when fired at low level from A-10 aircraft using operational tactics.

To conduct the LAVP program, the Armament Directorate has cooperated with Headquarters, Tactical Air Command, Langley AFB, Virginia and, in turn, with the Tactical Fighter Weapons Center, Nellis AFB, Nevada. Within the framework of that cooperation, the Armament Directorate has set up a Combat Damage Assessment Team (CDAT) to plan and execute the firing tests and evaluate the results. The CDAT functions under the direction of a Combat Damage Assessment Committee (CDAC) which has prepared this report of the firing test of 19 September, 1979.

TEST PHILOSOPHY

To generate realistic data, the CDAC determined to use a highly empirical technique of destructive testing of actual tank targets. Tests have involved firings at individual tanks in November, 1977 and February - March, 1978, and, more recently, arrays of vehicles in tactical formations. The experimental setup for the firings of 19 September, 1979 involved the use of a multi-target, tactically arrayed tank formation for attack by the A-10/GAU-8 system. The CDAT elected to simulate a Soviet tank company, as organized within a tank division, as the target array for two attacking A-10 aircraft. As few constraints as possible were placed on the attacking pilots in an attempt to develop as much realism as possible. Table II shows the test factors which would have been ideal in the test of 19 September, 1979 and the practicable setup which was achieved.

Table II. Comparison of Ideal and Practical Test Situations

<u>Ideal Test Parameters</u>	<u>Practical Test Parameter</u>
<p>1. <u>Air Attack Realism</u></p> <ul style="list-style-type: none"> a. Actual A-10/GAU-8 b. 30mm API c. European weather & terrain d. Optimum open-fire ranges (2000 ft) e. Low altitude attack angle (< 6 degrees) <p>2. <u>Air Defense Realism</u></p> <ul style="list-style-type: none"> a. Automatic cannon firing at aircraft b. Missile systems firing at aircraft c. Small arms firing at aircraft d. AD suppression by aircraft <p>3. <u>Threat Targets and Doctrine</u></p> <ul style="list-style-type: none"> a. T62/T64/T72 high fidelity targets b. Stowed combat loads (in T62/T64/T72) c. Realistic crew station postures d. Dynamic combat formation e. Maneuvering evasive targets 	<p>1. <u>Air Attack Realism</u></p> <ul style="list-style-type: none"> a. Actual A-10/GAU-8 b. 30mm API c. Nevada weather & desert terrain d. Average open-fire range: 3658 feet. e. Low altitude attack angle (< 6 degrees) <p>2. <u>Air Defense Realism</u></p> <ul style="list-style-type: none"> a. Low-altitude, low-angle, minimum-exposure attacks versus assumed AD system b. Low-altitude, low-angle, minimum-exposure attacks versus assumed AD system c. Low-altitude, low-angle, minimum-exposure attacks versus assumed AD system d. No suppression simulation in test <p>3. <u>Threat Targets and Doctrine</u></p> <ul style="list-style-type: none"> a. Simulated Soviet tanks b. Stowed combat loads (in US M-47) c. Wooden crew manikins d. Static combat formation e. Stationary targets

SIMULATED GROUND COMBAT SITUATION

The firing test of 19 September, 1979 simulated the attack by two A-10 aircraft on a Soviet tank company. The CDAC hypothesized the Soviet tank company to be the lead march security detachment for its battalion, which in turn, is the advance guard of a larger mobile formation. The lead detachment operates approximately five kilometers in front of the Soviet battalion column. The mission of the advance company is to ensure the uninterrupted advance of the battalion and provide security against attack. Upon meeting heavy resistance, the company deploys into an appropriate combat formation to reduce the resistance, or form a base of fire for offensive action by the remainder of the battalion.

A Soviet tank company would probably have other units attached to it for its support. Attached units might include any one or all of the following elements: (1) motorized rifle platoon; (2) engineer detachment; (3) chemical defense specialists; (4) 122mm howitzer battery; (5) air defense element. The company simulated in the firing test consisted of tanks alone. The pure tank formation was arranged in column formation, simulating high speed movement along an axis of advance. The tanks used in the firing test were US M-47 tanks, largely intact, containing crew manikins, and stowed with ammunition, fuel, and oil. The tanks were not maneuvered during the firing test and the formation remained essentially a snapshot of the company at a single point in time.

TARGET TANKS

The most effective tanks available in sufficient numbers to simulate Soviet T-55 and T-62 (Figure 1) tanks were the US M-47 tanks. Both of the Soviet tank models are similar in armor protection to the M-47. With the appropriate purging of the gasoline fuel system of the US tanks, the CDAT managed to field a tank similar in survivability to the T-55 and T-62 tanks from the viewpoint of ignitable internal material. Few data are available on the Soviet T-64 and later model tanks from the viewpoints of armor protection and the arrangement of internal components. The decision was made, accordingly, to simulate the earlier model Soviet tanks with the readily available US tanks.

The M-47 tanks used for targets were in excellent condition from the viewpoint of damage assessment. The exterior components were complete and the tanks have proven to be effective targets for the collection of exterior mobility damage. Interior components were less complete in the target tanks. All of the most essential items were present, e.g., main gun, engine, transmission, fuel tanks, ammunition racks, etc., but other items such as oil coolers, range finders, vision devices, and radios, have not been present in all tanks.

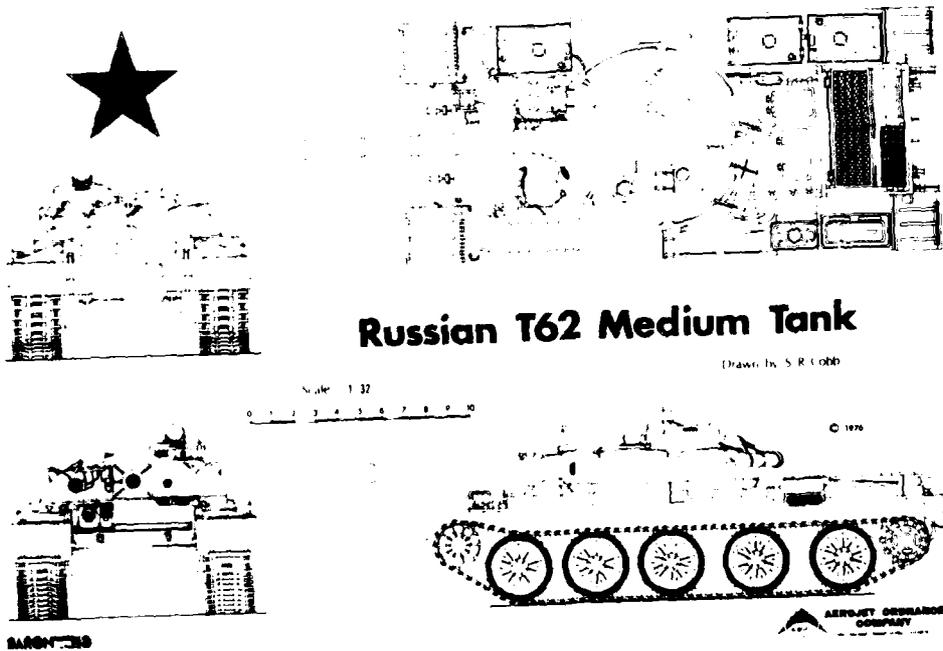
The most sensitive internal items from the viewpoint of catastrophic kills and high percentage Mobility (M) and Firepower (F) kills are the following, which were placed in the test tanks as noted:

<u>Generic Sensitive Item</u>	<u>Test Item</u>
1. Ammunition -----	US Cartridge, 90-mm TP-T
2. Fuel -----	Number 2 Diesel
3. Oil -----	Oil in Engine, Transmission and Drive Components.
4. Personnel -----	Articulated Plywood Manikins

The tanks were static during the test and their engines were not running, with the result that the fuel and oil were much cooler and more inert than would have been the case with a moving tank or a static vehicle with its engine running. The kill ratio achieved in the firing test of 19 September, 1979, therefore, is probably conservative from the viewpoint of fires resulting from ignited fuel and oil.

TEST PERFORMANCE AND RESULTS

Conduct of the test consisted of bringing together the ammunition, gun, aircraft, pilots, and combat arrayed and loaded tanks into a several minutes simulation of combat. In essence, the



Russian T62 Medium Tank

Drawn by S.R. Cobb

Scale: 1:32

C 1976

AEROSPACE COMPANY

FIGURE 1. Russian T62 Medium Tank

decisive elements which were fed into the test immediately prior to the firing were the following:

1. Aerojet 30mm API ammunition, Lot Number AJD 79A181-001.
2. General Electric GAU-8 Gatling gun.
3. Fairchild Republic A-10 attack aircraft.
4. USAF Fighter Pilots.
5. US Designed M-47 main battle tanks.

The combat simulation itself comprised the aerial fire and maneuver of the attacking A-10 aircraft. A realistic way of presenting the combat simulation is to outline the sequence of pertinent events in each firing pass. These events and the pertinent data which the CDAT attempted to collect, in order to reconstruct the simulated combat firing of 19 September, 1979, were as follows:

<u>Sequence</u>	<u>Event</u>	<u>Data</u>
1.	Aircraft Approach	Speed, Altitude
2.	Aircraft Attack	Open-fire Range, Dive Angle
3.	Aircraft Attack	Burst Time, Rounds Fired
4.	Aircraft Attack	Cease-fire Range, Dive Angle
5.	Gun Effects, (Accuracy)	Impacts on Tanks
6.	Gun Effects, (Lethality)	Perforations through Armor
7.	Tank Damage	Catastrophic (K-Kill), Mobility (M-Kill), and Firepower (F-Kill) Kills

The data noted immediately above were collected through the combined efforts of the CDAT and range support personnel at Nellis AFB, working together and using TSPI equipment, motion picture and still cameras, the industrial efforts required to repair, refurbish, and field the tank targets, and various systematic research techniques used to describe weapon effects and combat damage. The most basic materiel used in the test; i.e., the aircraft, gun, and projectile are illustrated in Figures 2, 3, 4, and 5. The tanks were arrayed in the tactical formation of a column of Soviet tanks as shown in Figure 6.

The pilots making the attack flew from the base area in a two-ship, mutually supporting element and employed operational tactics immediately before and during the firing passes. The pilots approached the target area at low altitude and simulated target acquisition with the help of a forward air controller. The pilots proceeded in their attack on the acquired targets at low altitudes and dive angles, simulating operation below the altitudes for effective acquisition and engagement by opposing air defense missile and gun systems.



FIGURE 2. U.S.A.F. Fairchild Republic A-10 Aircraft.

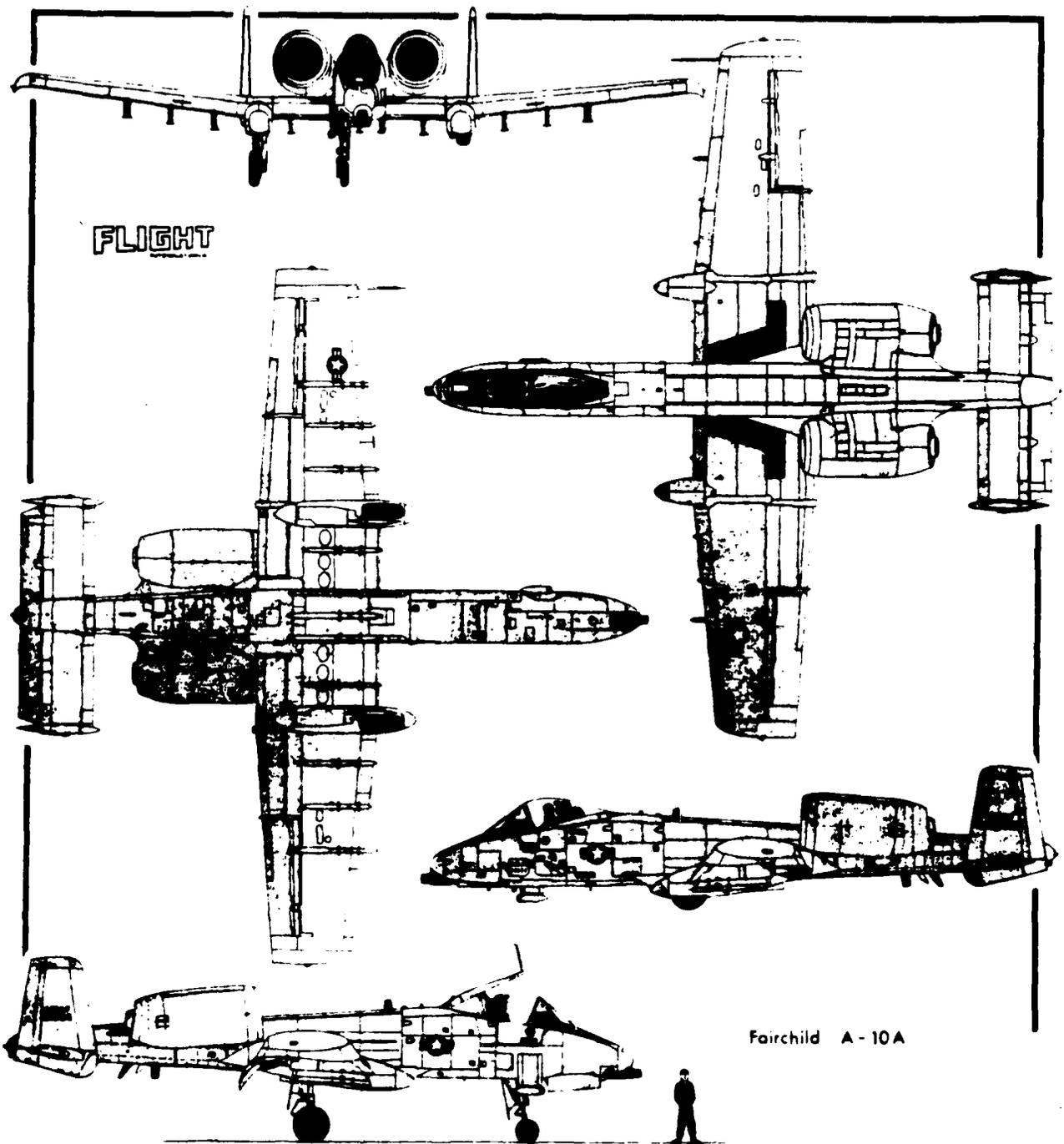


FIGURE 3. Fairchild A-10 Series Aircraft.

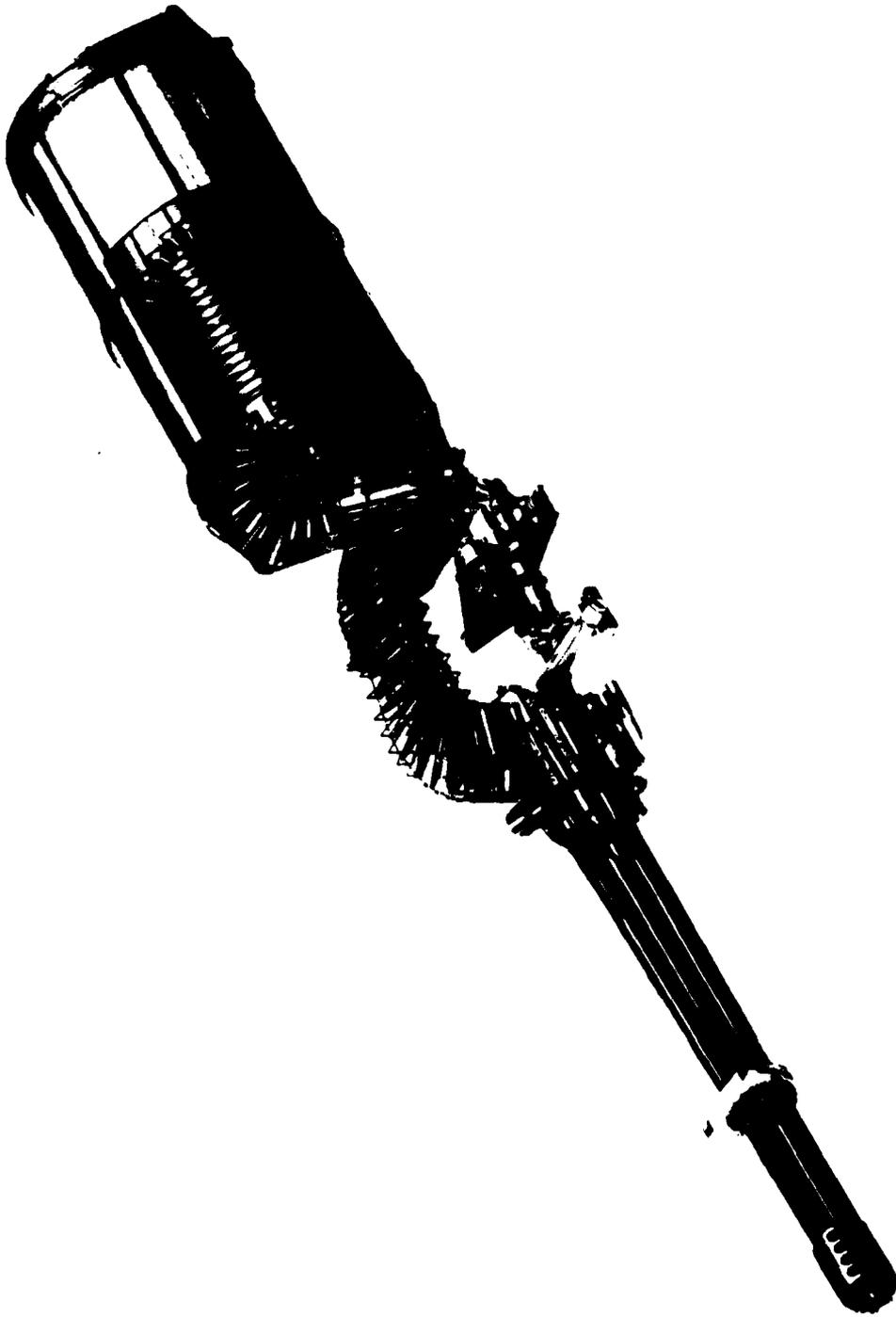


FIGURE 4. GAU-8/A 30mm Gun System

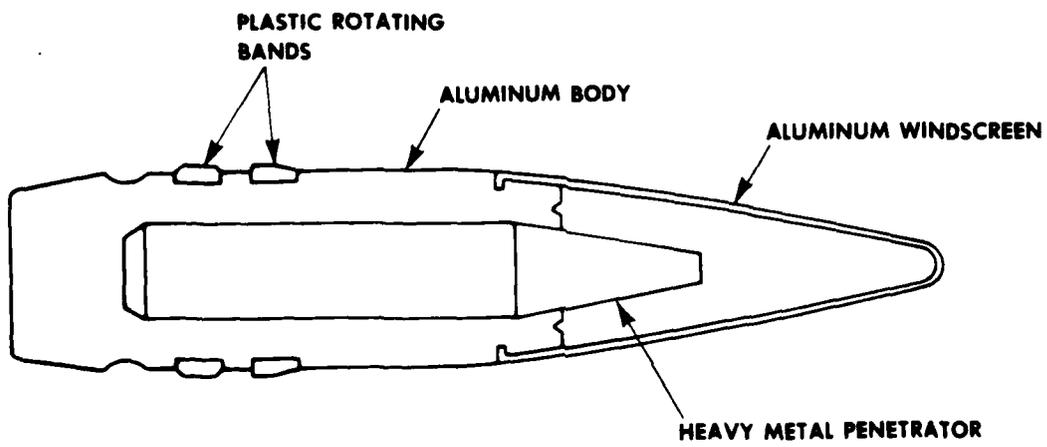


FIGURE 5. 30mm Armor Piercing Incendiary (API) Projectile.

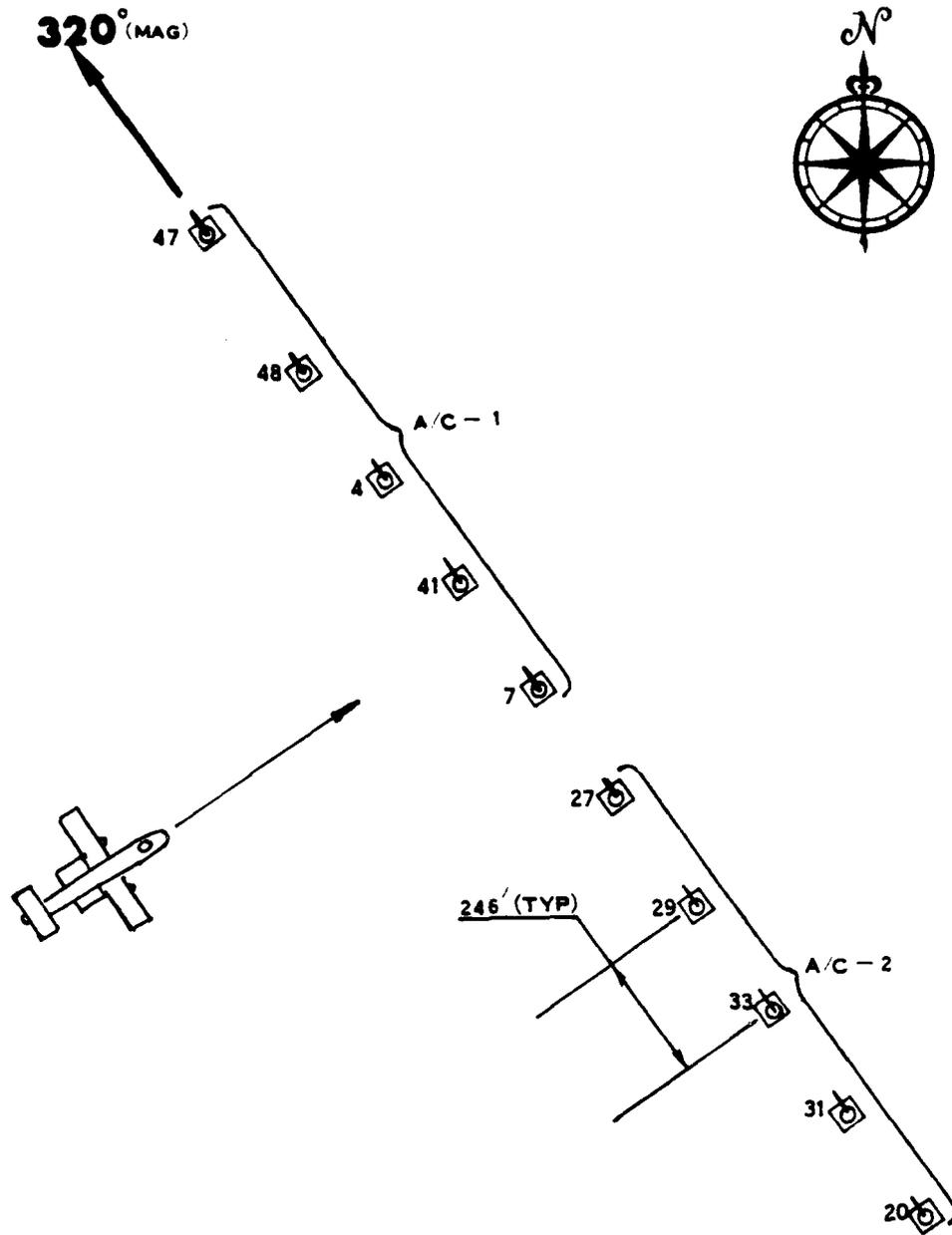


FIGURE 6. Approximate Target Layout.

DAMAGE ASSESSMENT

The damage assessment conducted by the CDAT is presented on the following pages. Appendix A, following the damage assessment section contains graphical and tabular information relative to the mission in general; for example, aircraft attack parameters, weapon effects, and summaries of damage.

Terms used in the damage assessment summaries are defined in Appendix B.

Impacts on tanks were arbitrarily numbered for identification purposes. The impacts were numbered sequentially, first at the turret level, then at the hull level. If additional impacts were discovered during the combat damage assessment (as was sometimes the case) they were given the next sequential number, i.e., no attempt was made to "correct" the sequence. THE READER IS CAUTIONED THAT THIS NUMBERING SYSTEM HAS NO RELATIONSHIP WHATSOEVER TO THE ARRIVAL SEQUENCE OF PROJECTILES ON THE TANK OR TO THE PORTION OF THE BURST IMPACTING THE TANK.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 47

1. Description:

The target tank was impacted at an attack aspect of 274 degrees (left side) during one firing pass at low altitude and low dive angle. The A-10 expended 92 rounds in the firing pass.

2. Kill Assessment:

100% M-Kill and 100% F-Kill resulting from the following observed projectile effects (Figure 7):

a. Perforations	:	3
b. Significant Impacts	:	6
c. Insignificant Impacts:		<u>16</u>
TOTAL IMPACTS	:	25

3. Rationale for Kill Assessment:

- a. M-Kill: The assessment of 100% M-Kill was based on impacts 7, 8, and 10 which perforated the left side of the turret killing the commander (Figure 8) and gunner and wounding the loader, driver, and bow gunner (Figure 9), impact 19 which destroyed the left number 1 road wheel hub, and impacts 13, 14, 15, 24, and 25 (Figure 10) which cumulatively damaged the track and suspension system.
- b. F-Kill: The assessment of 100% F-Kill is based on crew casualties to all five crew members.

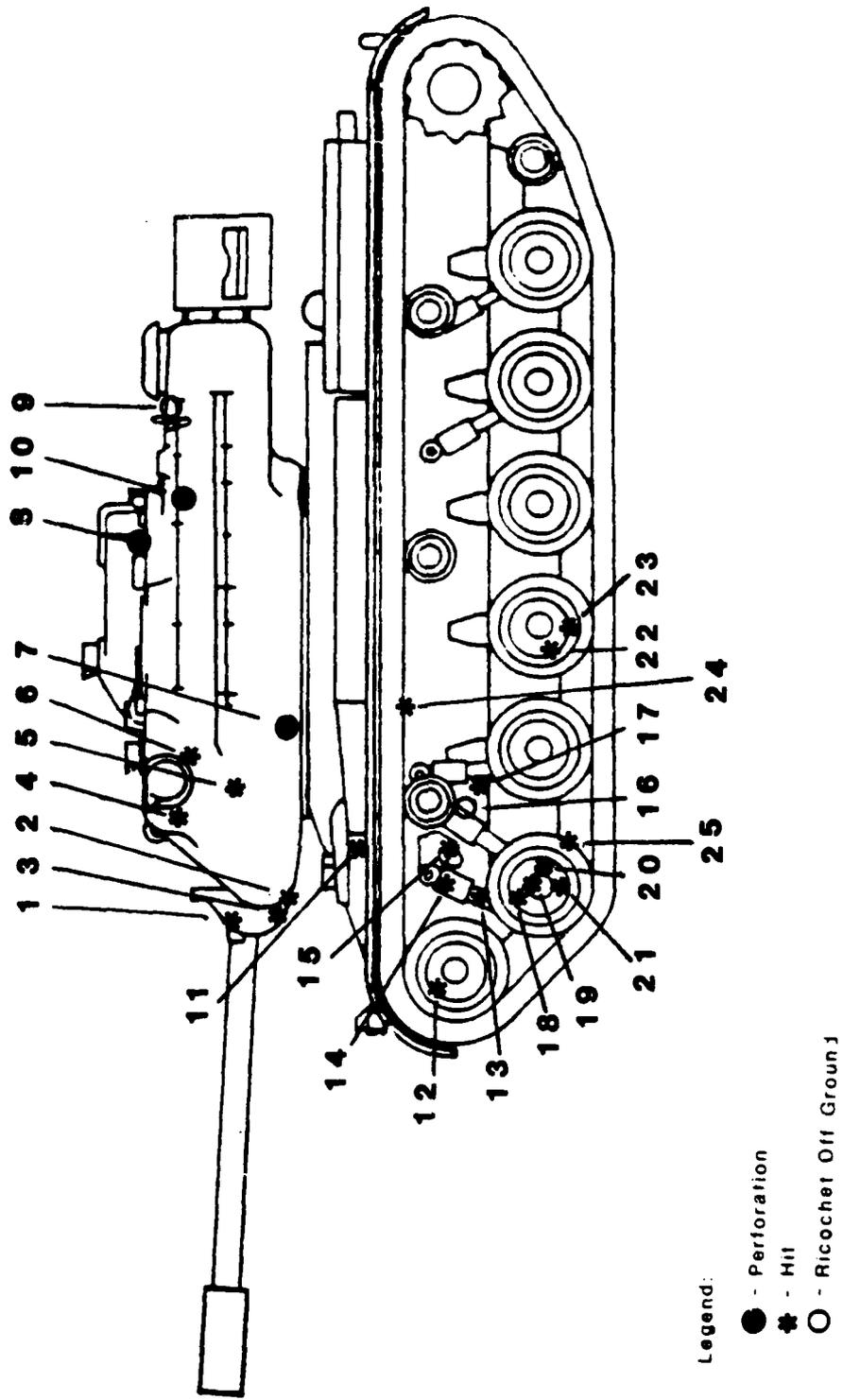


FIGURE 7. Impact Diagram, Tank 47.



FIGURE 8. Fragment Damage to Commander Manikin from Impacts
7, 8, and 17.

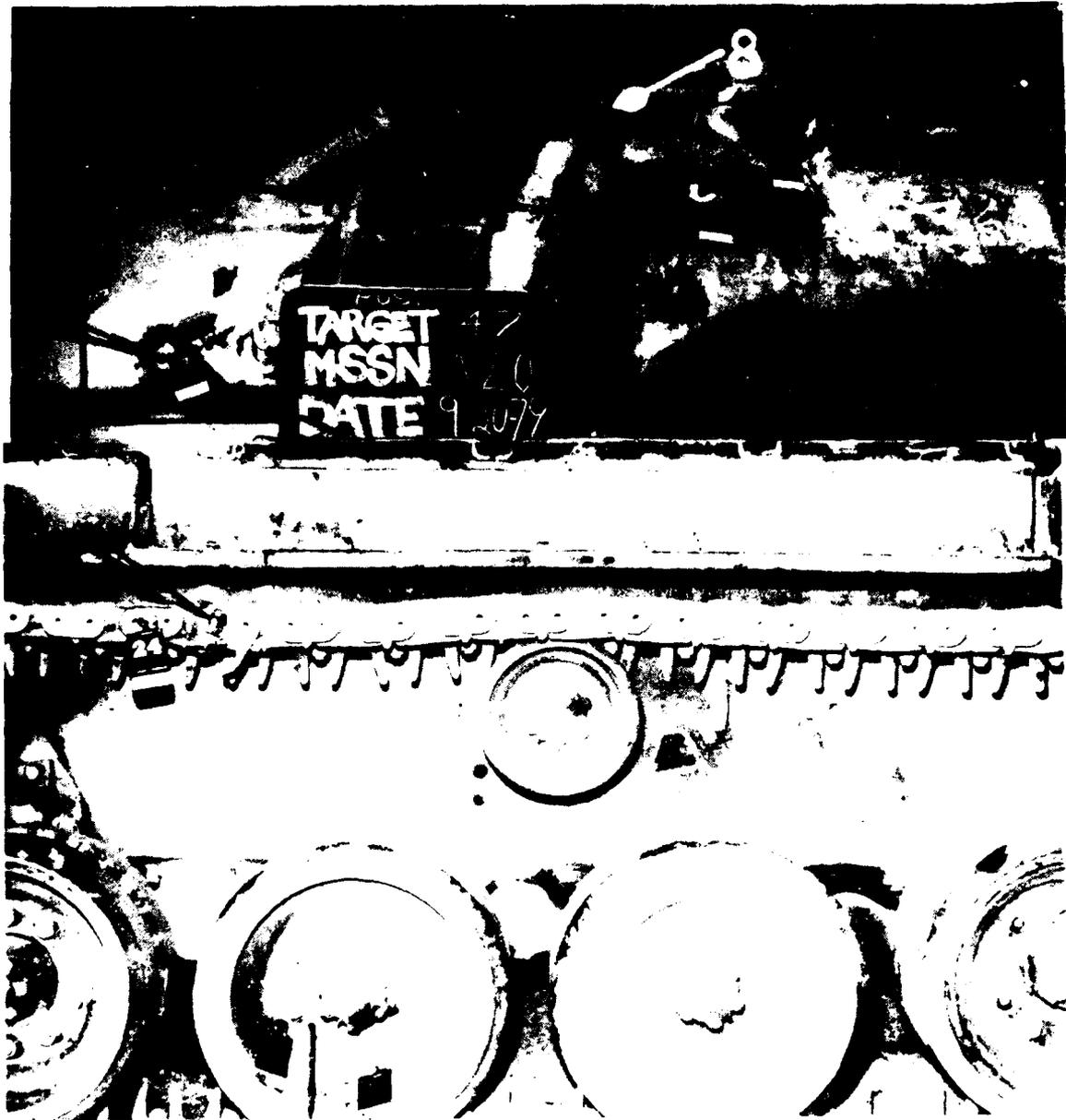


FIGURE 9. Impact 2, Perforation of Left Turret, Tank 47.



Figure 1. Damage to Track and Suspension System caused by
Tanks 13, 14, 15, 24, and 25; Tank 47.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 48

1. Description:

The target tank was impacted at an attack aspect of 273 degrees (left side) during one firing pass in which the attacking aircraft expended 129 rounds.

2. Kill Assessment:

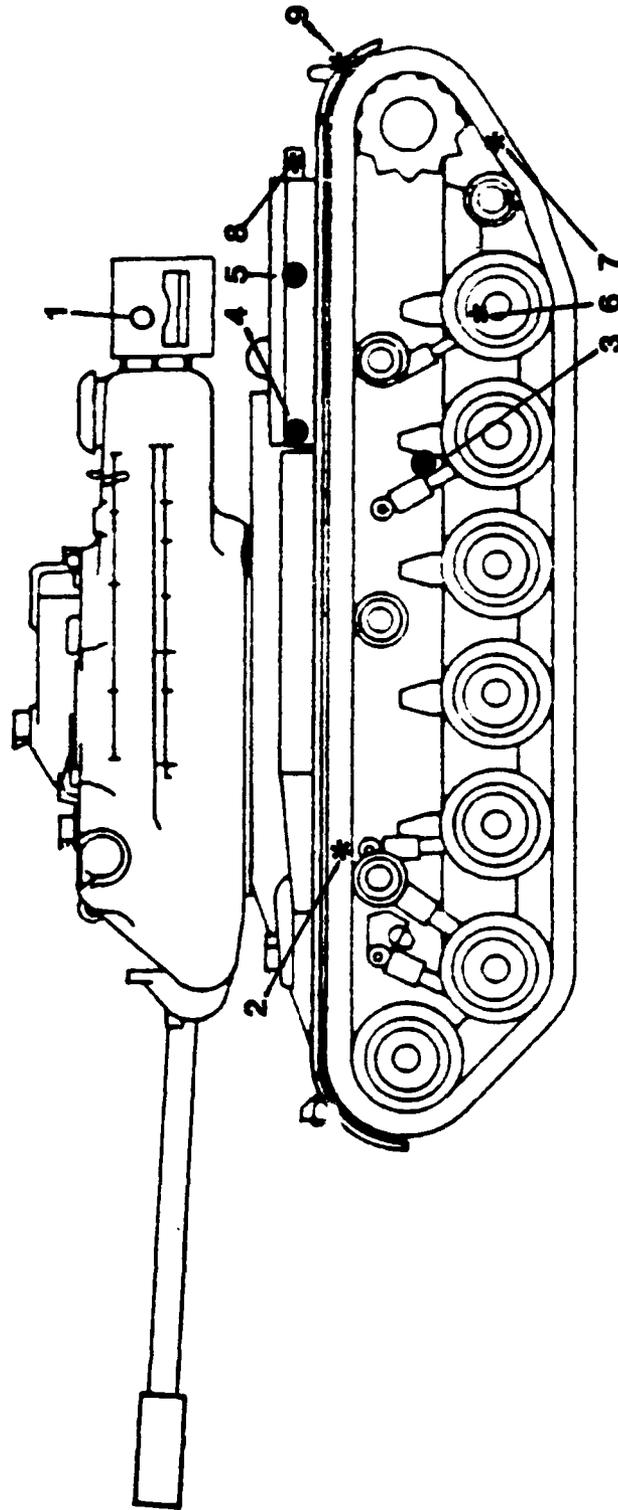
100% M-Kill based on the following observed effects (Figure 11):

a. Perforations	:	3
b. Significant Impacts	:	1
c. Insignificant Impacts:		<u>5</u>

TOTAL IMPACTS	:	9
---------------	---	---

3. Rationale for Kill Assessment:

The assessment of 100% M-Kill is based on impact 3, which perforated the left hull and penetrated into the left fuel cell, and impact 5, which perforated the left hull into the engine compartment destroying the coupling on the oil cooler inlet line from the transmission (Figure 12).



Legend:

- - Perforation
- * - Hit
- - Ricochet Off Ground

FIGURE 11. Impact Diagram, Tank 48.

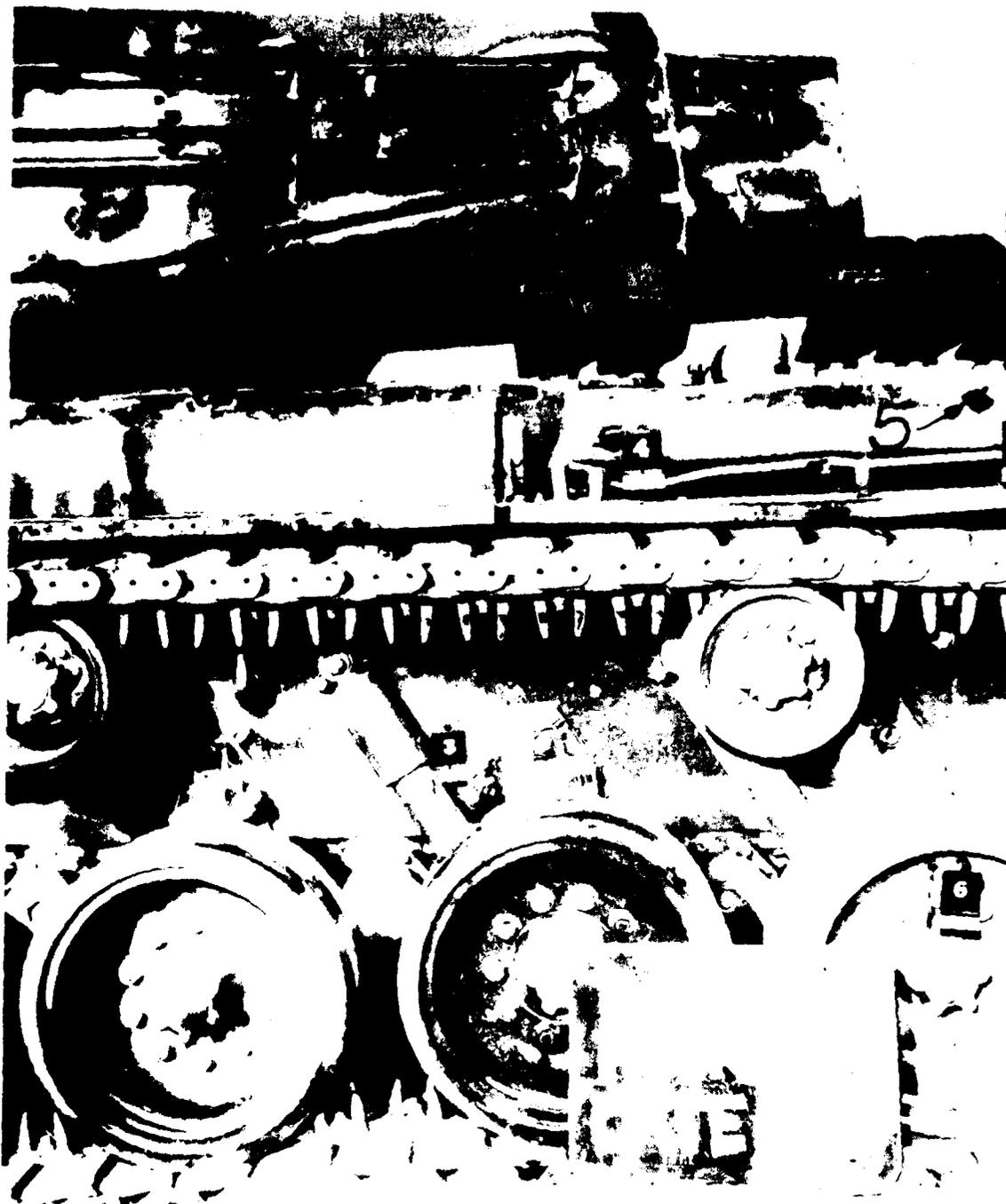


FIGURE 12. Perforation 5 Destroyed Oil Cooler Inlet Line from Transmission, Tail Ho.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 4

1. Description:

The target tank was impacted at an attack aspect of 275 degrees (left side) during one firing pass in which the attacking aircraft expended 137 rounds.

2. Kill Assessment:

90% M-Kill and 95% F-Kill resulting from the following observed effects (Figures 13):

a. Perforations	:	5
b. Significant Impacts	:	0
c. Insignificant Impacts:		<u>19</u>

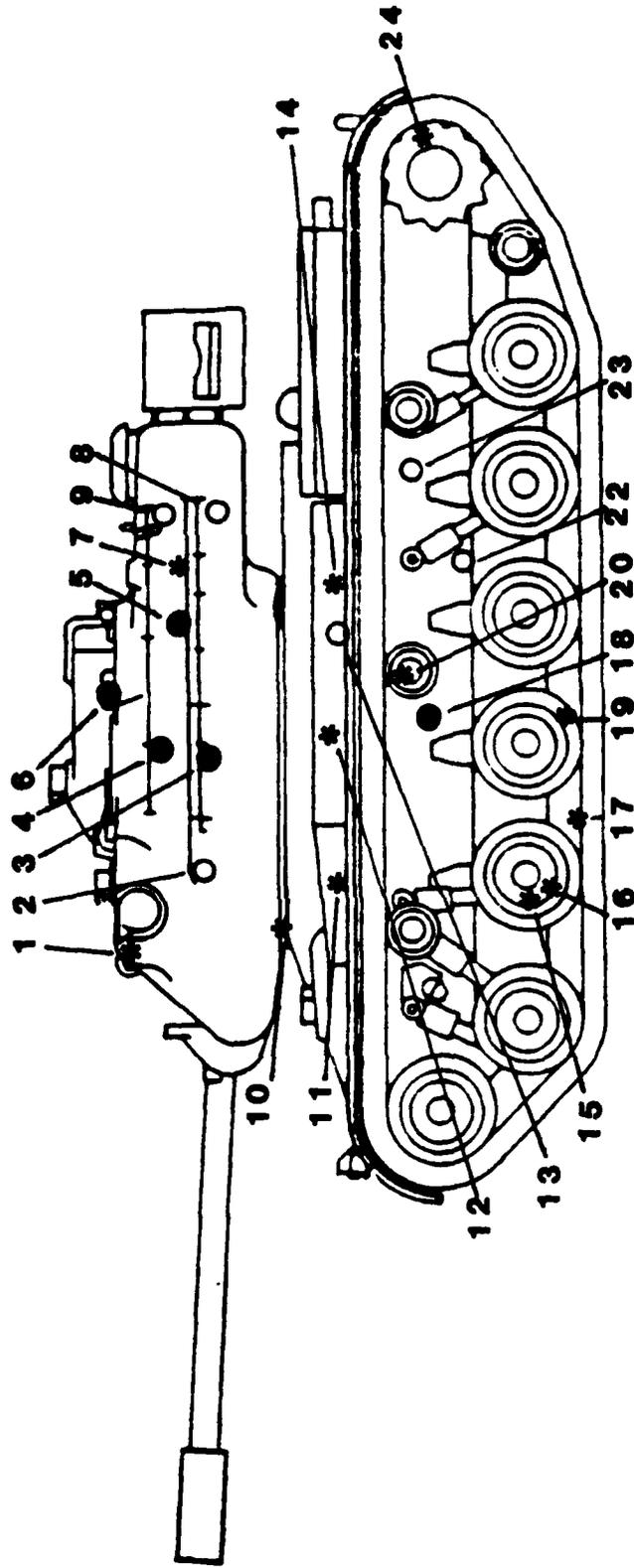
TOTAL IMPACTS	:	24
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3. Rationale for Kill Assessment:

a. M-Kill: The assessment of a 90% M-Kill is based on casualty criteria resulting from impacts 3, 4, 5, and 6 (Figure 14) which caused casualties to all crewmen in the fighting compartment. The tank could continue its mission after replacement of the wounded crewmen.

b. F-Kill: The assessment of a 95% F-Kill is also based on casualty criteria. The tank could continue its mission after replacement of the wounded crewmen.

NOTE: Number 21 not depicted.



Legend:
● - Perforation
★ - Hit
○ - Ricochet Off Ground

FIGURE 13. Impact Diagram, Tank 4.



FIGURE 14. Crew Casualties Resulting from Impacts 3, 4, 5, and 6; Tank 4.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 41

1. Description:

The target tank was impacted at an attack aspect of 274 degrees (left side) during one firing pass in which the attacking aircraft expended 126 rounds.

2. Kill Assessment:

100% M-Kill and 100% F-Kill resulting from the following observed effects (Figures 15 and 16):

a. Perforations	:	4
b. Significant Impacts	:	8
c. Insignificant Impacts:		<u>28</u>

TOTAL IMPACTS	:	40
---------------	---	----

3. Rationale for Kill Assessment:

- a. M-Kill: The assessment of a 100% M-Kill is based on impact 29 which perforated the left hull armor and penetrated the fuel tank; to impact 8 (Figure 17) which wounded all personnel in the fighting compartment; and to cumulative damage to the track and suspension system resulting from impacts 13, 15, 20, 22, and 33 (see Figure 18 for impacts 13, 20, and 22).
- b. F-Kill: The assessment of 100% F-Kill is based on impacts 9, 10, and 11, which jammed the turret and prevented it from traversing (Figure 19); and impact 8 which incapacitated the tank commander, gunner and loader.

NOTE: Number 35 is a ricochet which is not depicted.

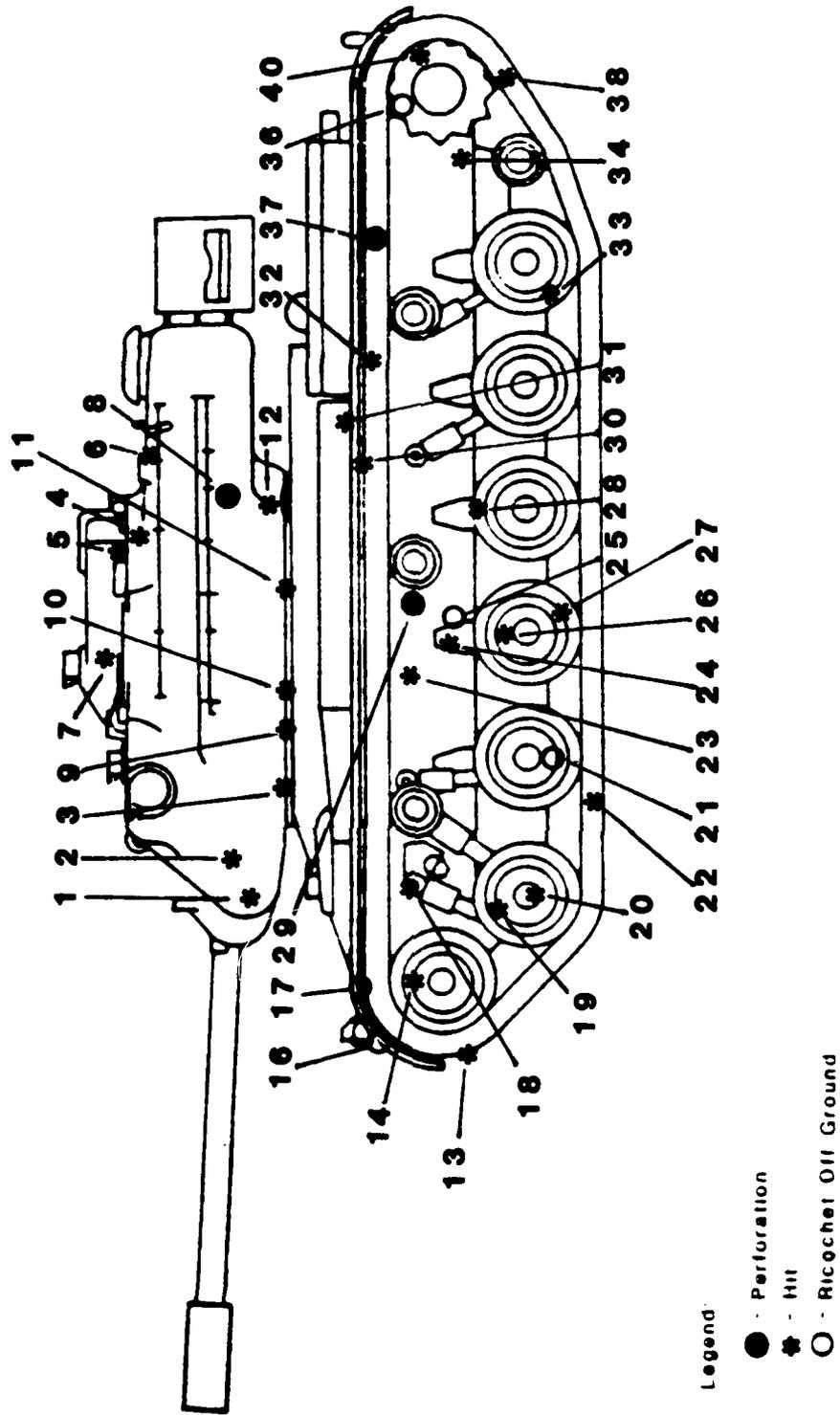
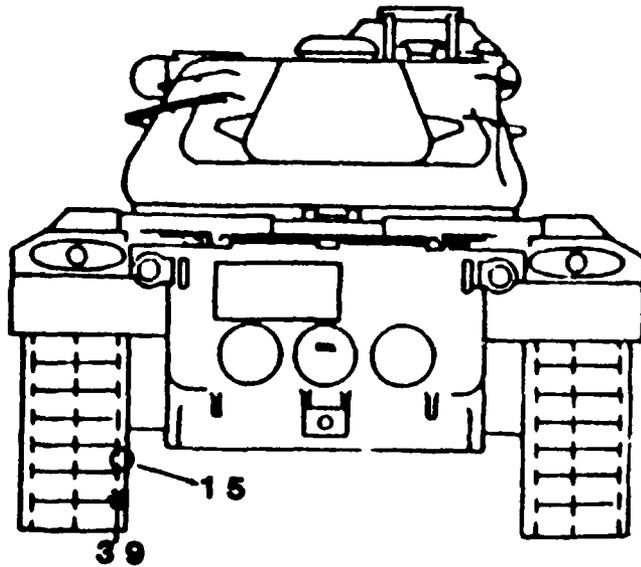


FIGURE 15. Impact Diagram, Tank 41, Left Side.



Legend:

- - Perforation
- ★ - Hit
- - Ricochet Off Ground

FIGURE 16. Impact Diagram, Tank 41, Rear.



FIGURE 17. Wounds Sustained by Tank Commander Markkin, Tank 41.

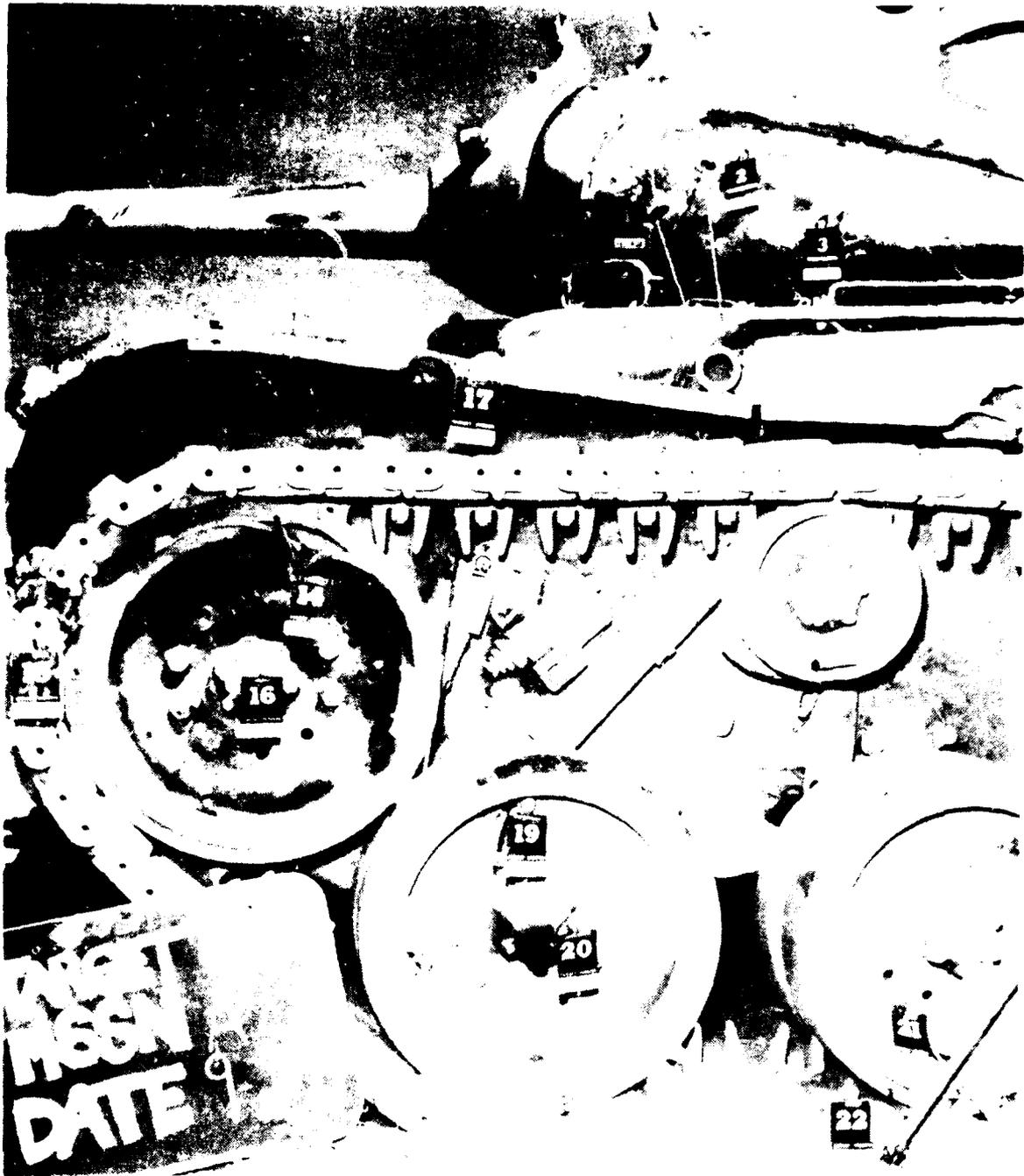


FIGURE 1. Diagram of Track and Suspension System, Tank 41.



PHOTOGRAPH OF THE INTERIOR OF THE AIRCRAFT, SHOWING THE SEATS AND THE TARGET MESSAGE BOARD.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 7

1. Description:

The target tank was impacted at an attack aspect of 272 degrees (left side) during one firing pass in which the attacking aircraft expended 258 rounds.

2. Kill Assessment:

100% (interdiction type) M-Kill and 20% F-Kill resulting from the following observed effects (Figure 20):

a. Perforations	:	3
b. Significant Impacts	:	11
c. Insignificant Impacts:		<u>15</u>

TOTAL IMPACTS	:	31
---------------	---	----

3. Rationale for Kill Assessment:

- a. M-Kill: The assessment of a 100% interdiction type M-Kill after 500 meters movement was attributed to impact 9 (Figure 21) which destroyed one end connector and one track center guide on the same pair of track links, and to cumulative damage to the track and suspension system caused by impacts 25, 26, 27, 29, (Figure 22) and six other impacts.
- b. F-Kill: A 20% F-Kill was assessed due to damage caused by impact 1, (Figure 20 and 21), which penetrated the bore evacuator and gun tube.

NOTE: Impact number 4 did insignificant damage to the storage box, and is not depicted.

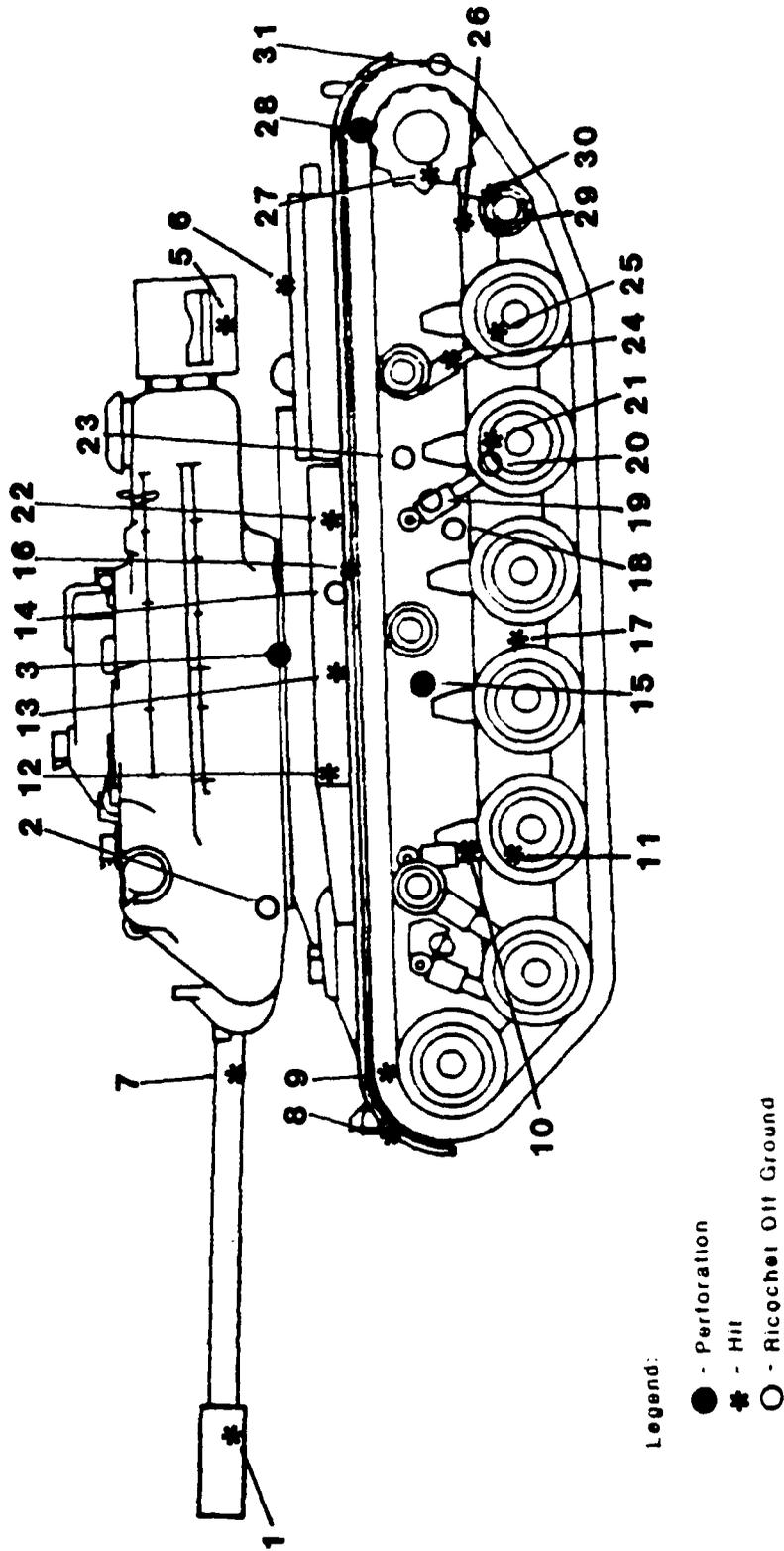


FIGURE 20. Impact Diagram, Tank 7.

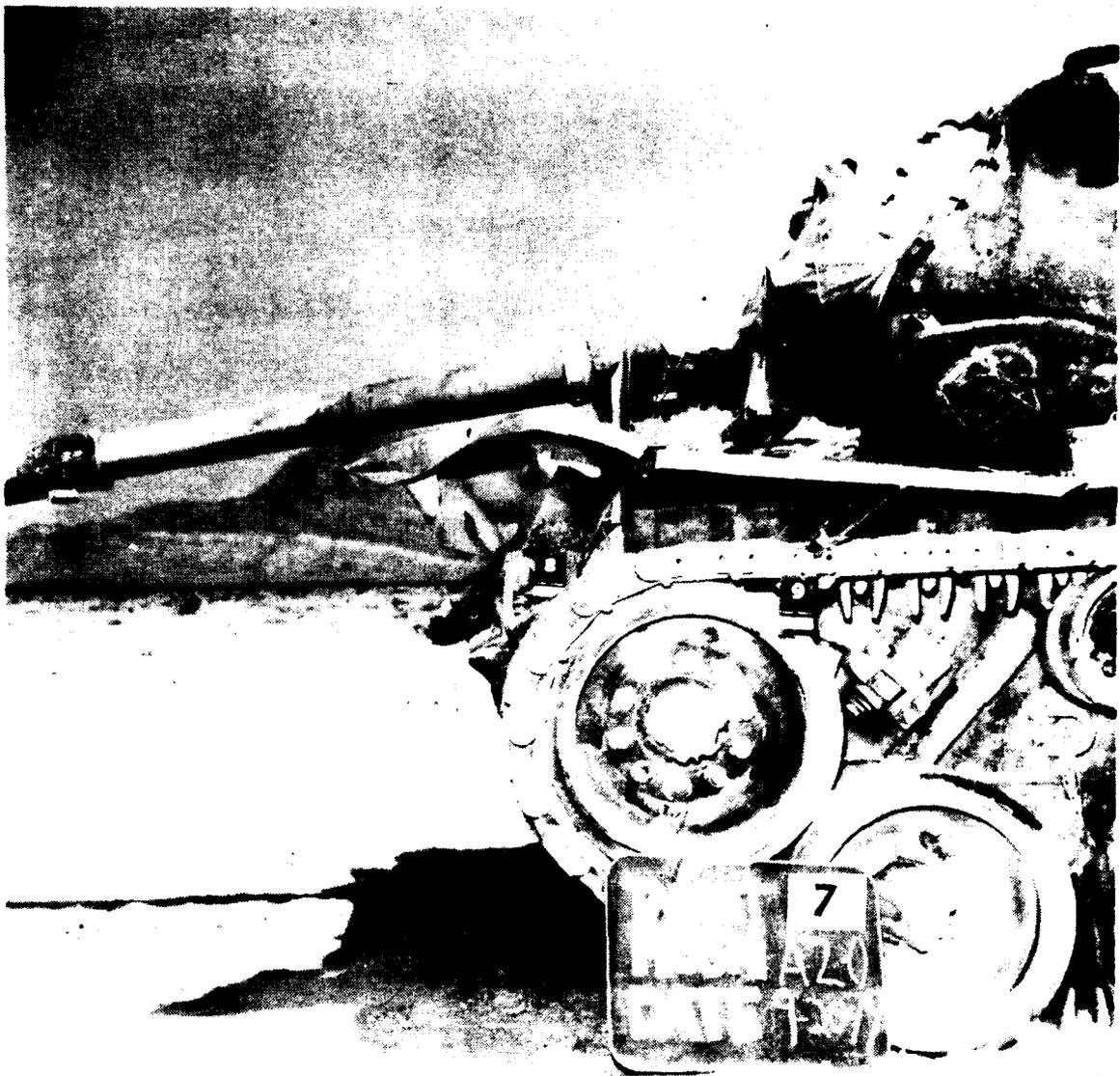


FIGURE 21. Damage to Track Connector and Center Guide
Caused by Impact 9; Tank 7.

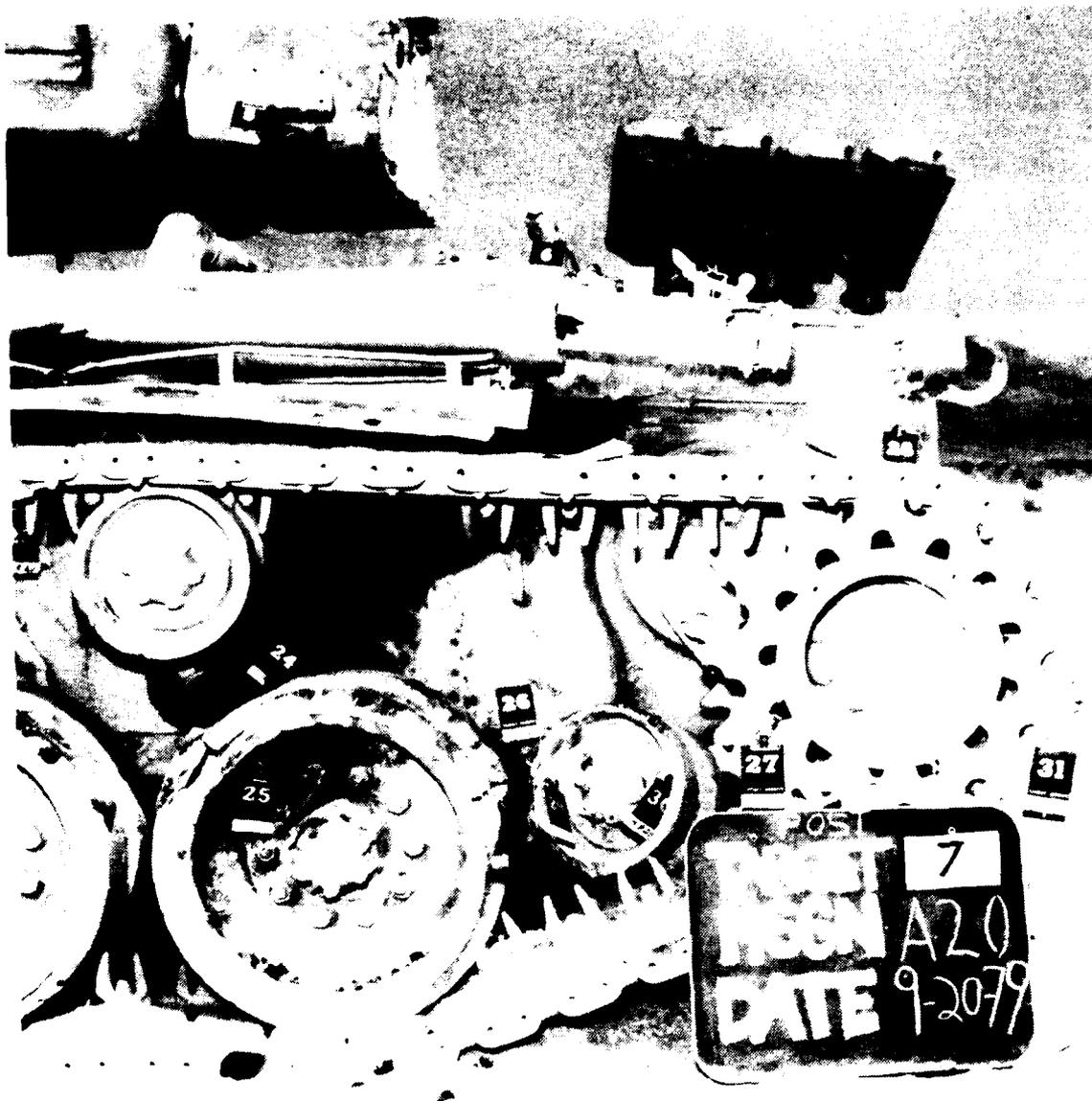


FIGURE 22. Extensive Damage to Track and Suspension System caused by Impacts 25, 26, 27, and 29; Tank 7.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 27

1. Description:

The target tank was impacted at an attack aspect of 272 degrees (left side) during one firing pass in which the attacking aircraft expended 70 rounds.

2. Kill Assessment:

100% K-Kill resulting from the following observed effects (Figure 23):

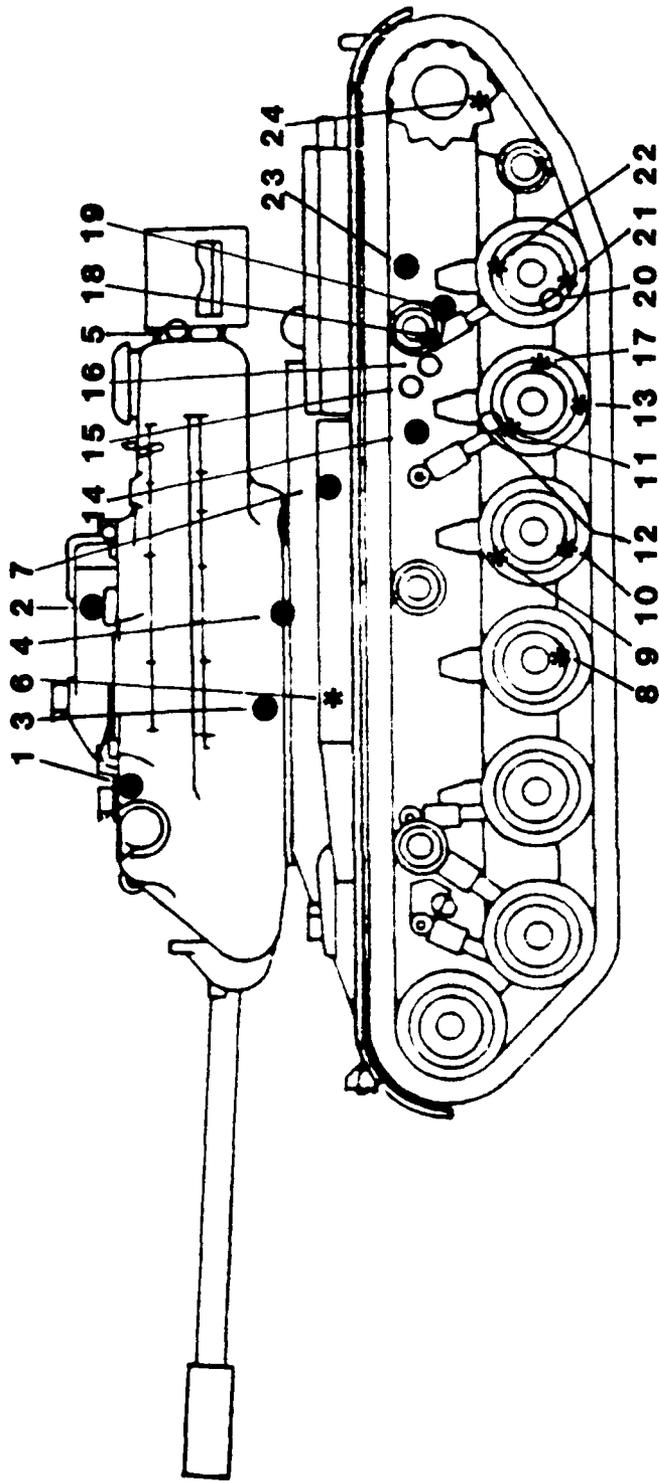
a. Perforations	:	8
b. Significant Impacts	:	**
c. Insignificant Impacts:		<u>**</u>

TOTAL IMPACTS : 24

**Omitted - catastrophic fire and explosions overrode other damage.

3. Rationale for Kill Assessment:

100% K-Kill due to a fuel fire resulting from impact 14 (Figure 24) which perforated the left hull armor and penetrated the fuel tank and impacts 1, 2, and 3, which perforated the turret causing crew casualties to all personnel in the fighting compartment. Impacts 7 (Figure 24), 19, and 23 (Figure 25) which penetrated into the engine compartment were also capable of igniting oil fed fuel fires.



Legend:

- - Perforation
- * - Hit
- - Ricochet Off Ground

FIGURE 23. Impact Diagram, Tank 27.



FIGURE 24. Impacts 7 and 14, Performance of 100 mm Hell Armor.



FIGURE 25. Impacts 19 and 23, Perforations into the Engine Compartment, Tank 27.

TARGET TANK DAMAGE SUMMARY

M-47 TANK NUMBER 29

1. Description:

The target tank was impacted at an attack aspect of 264 degrees (left side) during one firing pass in which the attacking aircraft expended 126 rounds.

2. Kill Assessment:

100% K-Kill resulting from the following observed effects (Figure 26):

a. Perforations	:	5
b. Significant Impacts	:	**
c. Insignificant Impacts:		<u>**</u>

TOTAL IMPACTS : 28

**Omitted - catastrophic fire and explosion overrode other damage.

3. Rationale for Kill Assessment:

100% K-Kill due to a fuel fire resulting from impact 20 (Figure 27) which perforated the left hull armor and penetrated the fuel tank and from impacts 2, 4, 8, and 12 (Figure 28) which perforated the turret and hull armor causing crew casualties to all personnel in the fighting and driver's compartment.

NOTE: Impact number 5 was a ricochet hit on left turret, not shown.

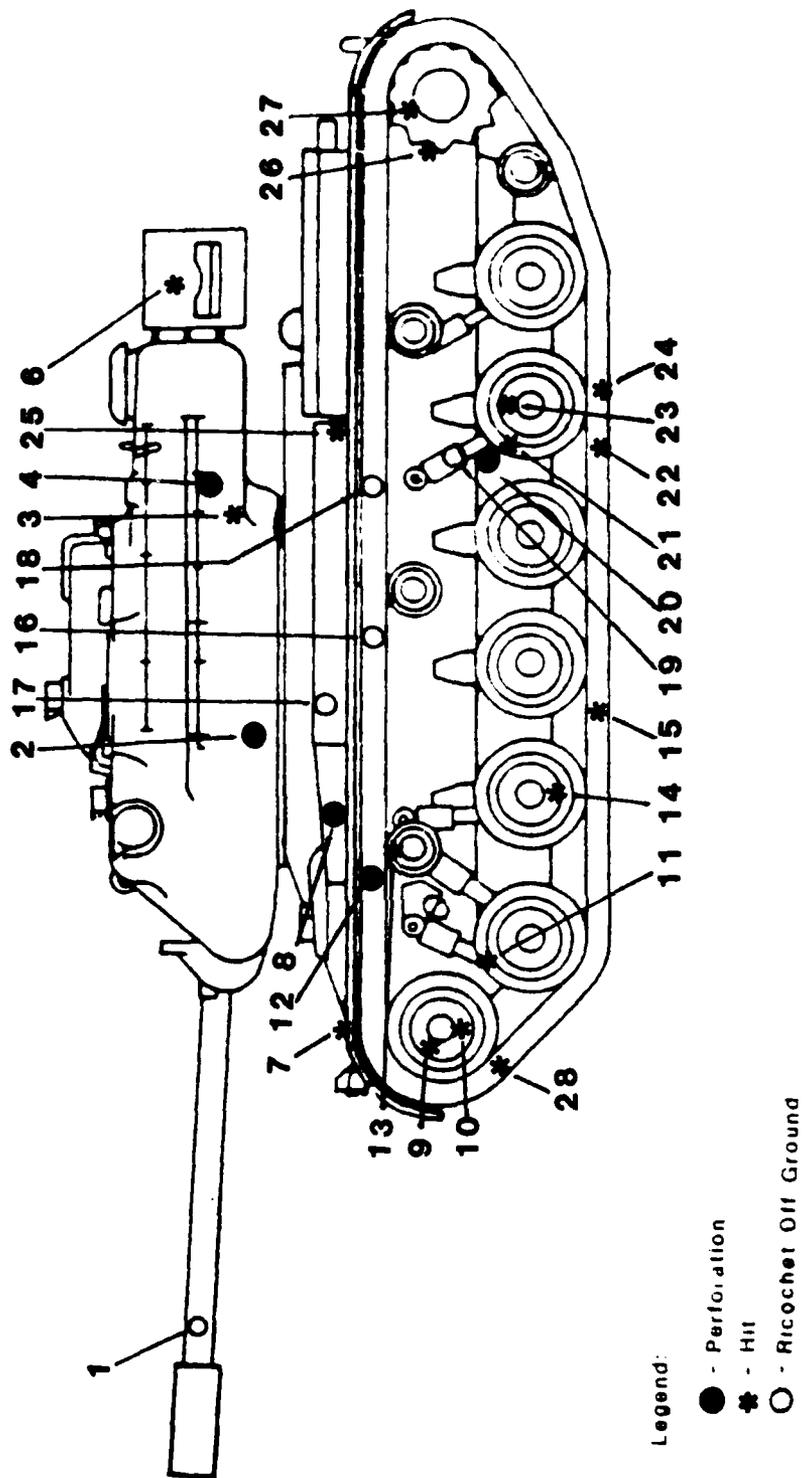


FIGURE 26. Impact Diagram, Tank 29.



FIGURE 27. Fuel for the Catastrophic Fire was provided by Impact 20, which perforated the left Fuel Tank, Tank 29.



FIGURE 25. Perforations by 4, 7, and 10 mm diameter projectiles initiated the crew, this view.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 33

1. Description:

The target tank was impacted at an attack aspect of 257 degrees (left side) during one firing pass in which the attacking aircraft expended 113 rounds.

2. Kill Assessment:

10% M-Kill and 30% F-Kill from the following observed effects (Figures 29 and 30):

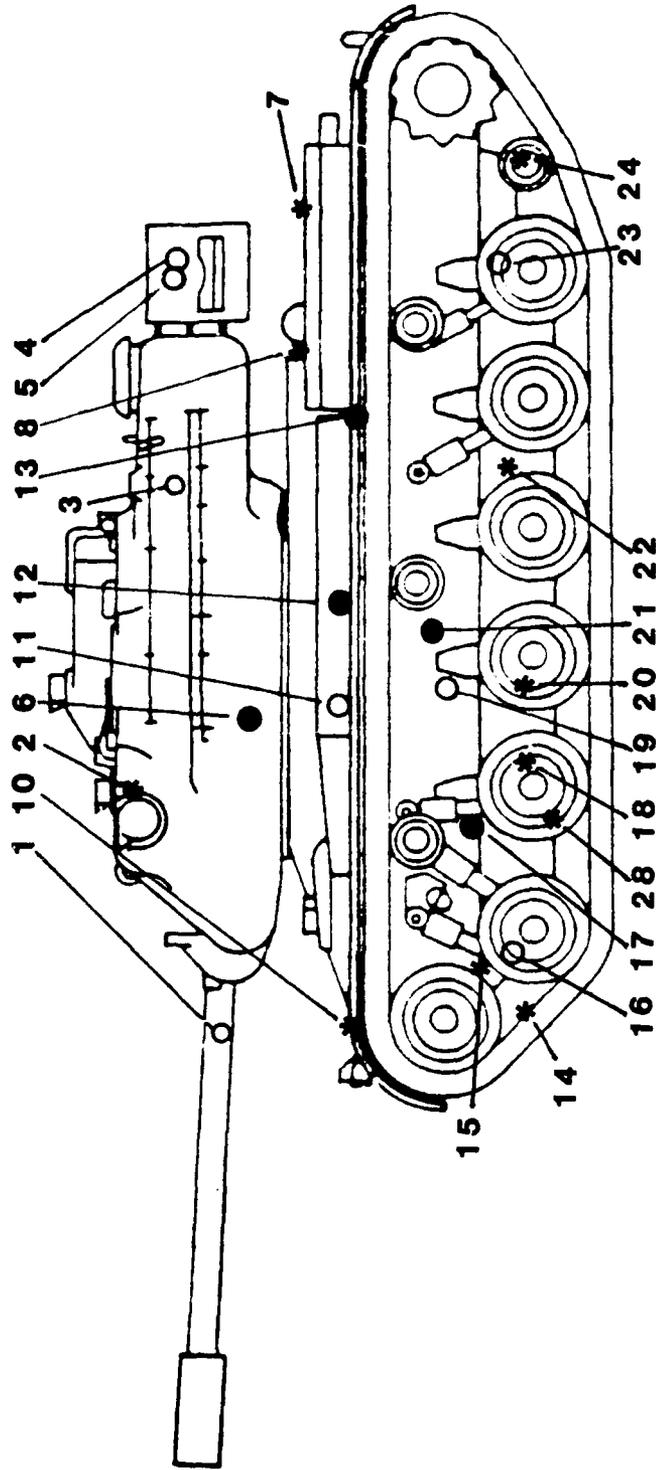
a. Perforations	:	5
b. Significant Impacts	:	2
c. Insignificant Impacts:		<u>21</u>

TOTAL IMPACTS	:	28
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3. Rationale for Kill Assessment:

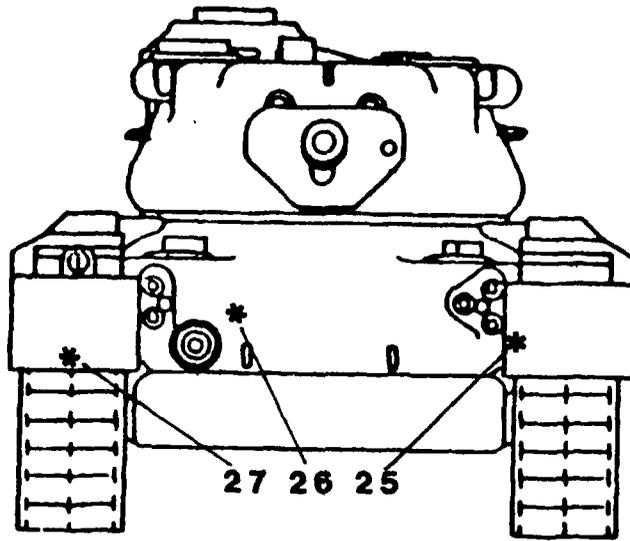
- a. M-Kill: A mobility degradation of 10% was assessed due to minor track and suspension damage caused by impacts 14 and 22
- b. F-Kill: A firepower degradation of 30% was assessed due to loader casualty (Figure 31) caused by impact 6 (Figure 32).

NOTE: Impact number 9 was a simple hit which is not depicted.



Legend:
 ● - Perforation
 * - Hit
 ○ - Ricochet Off Ground

FIGURE 29. Impact Diagram, Tank 33, Left Side.



Legend:

- - Perforation
- * - Hit
- - Ricochet Off Ground

FIGURE 30. Impact Diagram, Tank 33, Front.

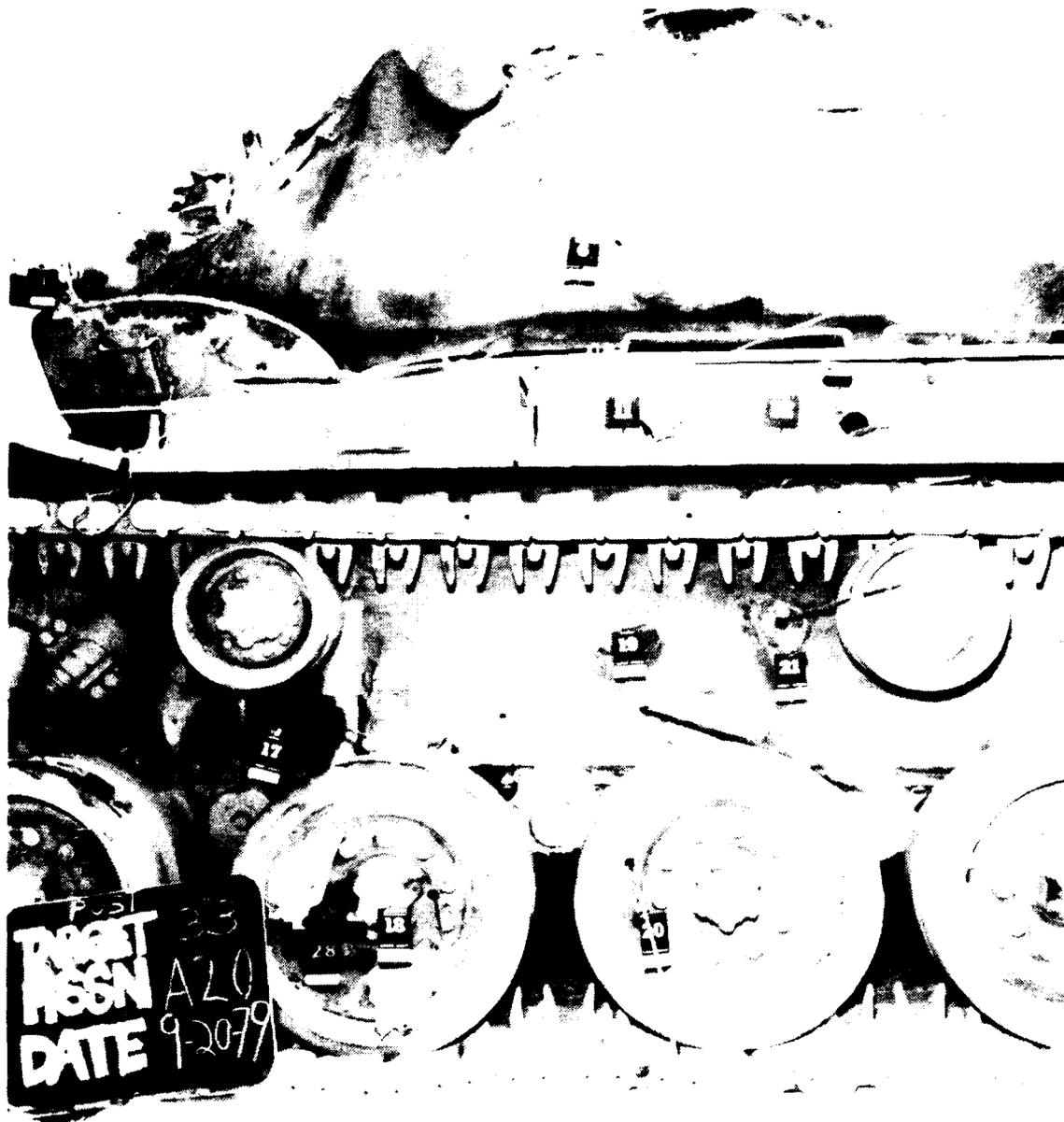


FIGURE 31. Impact 6 which Perforated the Turret and caused Loader Casualty, Tank 33.



FIGURE 32. Damage to Loader Manikin (arrow) caused by Impact 6; Tank 33.

TARGET TANK DAMAGE SUMMARY

M-47 Tank Number 31

1. Description:

The target tank was impacted at an attack aspect of 263 degrees (left side) during one firing pass in which the attacking aircraft expended 137 rounds.

2. Kill Assessment:

100% M-Kill and 95% F-Kill resulting from the following observed effects (Figure 33):

a. Perforations	:	2
b. Significant Impacts	:	3
c. Insignificant Impacts:		<u>17</u>

TOTAL IMPACTS	:	22
---------------	---	----

3. Rationale for Kill Assessment:

- a. M-Kill: The assessment of a 100% M-Kill is based on impact 17 (Figure 34) which perforated the left hull and penetrated the fuel tank, and on track and suspension damage resulting from impacts 16, 19, and 22.
- b. F-Kill: The assessment of a 95% F-Kill is based on assessed casualties to crew members in the fighting compartment (Figures 35, 36, and 37) caused by impact 2.

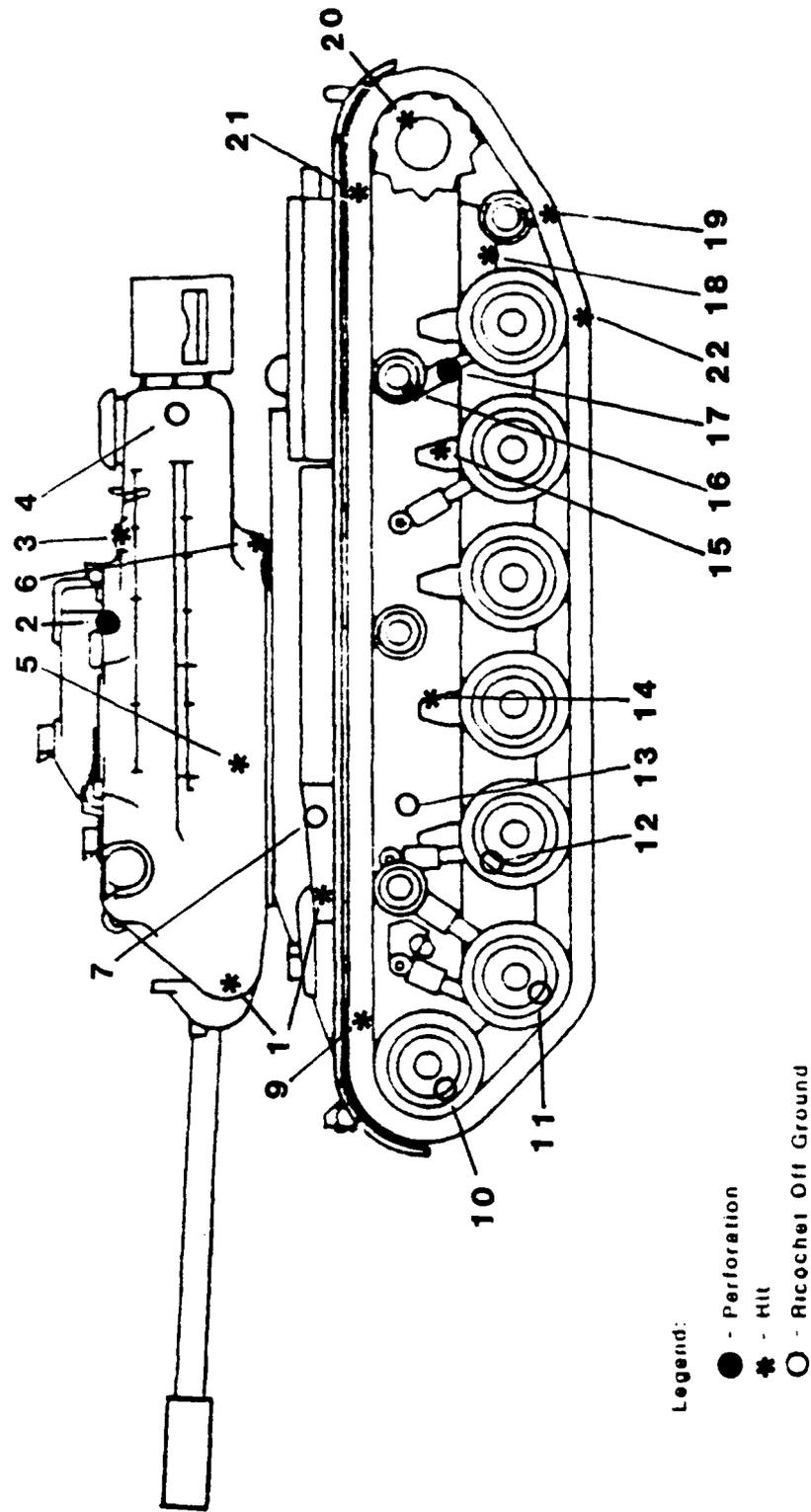


FIGURE 33. Impact Diagram, Tank 31.

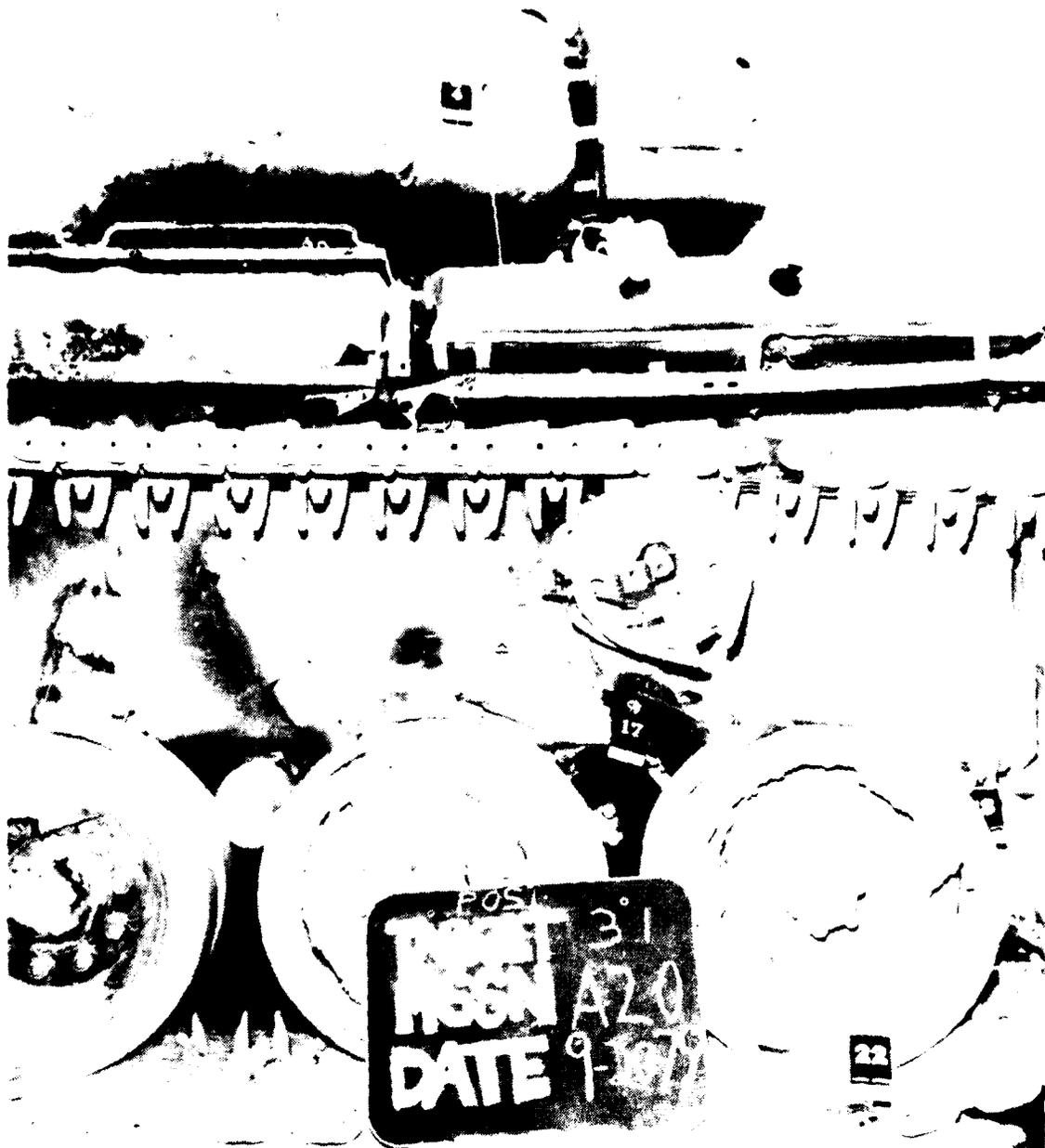


FIGURE 34. Impact 17, Perforation of Hull and Fuel Tank, Tank 31.



FIGURE 35. Damage to Commander Manikin caused by Impact 2, Tank 31.



FIGURE 36. Damage to Gunner Manikin caused by Impact 2, Tank 31.



FIGURE 37. Damage to Loader Number caused by Impact 2, Tank 31.

TARGET TANK DAMAGE SUMMARY

M-47 TANK NUMBER 20

1. Description:

The target tank was impacted at an attack aspect of 260 degrees (left side) during one firing pass in which the attacking aircraft expended 161 rounds.

2. Kill Assessment:

Catastrophic (K-Kill) resulting from the following observed effects (Figure 38):

a. Perforations	:	4
b. Significant Impacts	:	**
c. Insignificant Impacts:		<u>**</u>

TOTAL IMPACTS : 12

**Omitted - catastrophic fire and explosion overrode other damage.

3. Rationale for Kill Assessment:

100% K-Kill due to a fuel fire resulting from impacts 8 and 9 (Figure 39) which perforated the left hull armor and penetrated the fuel tank and from impact 1 (Figure 40) which perforated the turret armor probably causing casualties to the commander, gunner, and loader.



Figure 8 and 9 Demonstrate
the use of a Mirror Filter

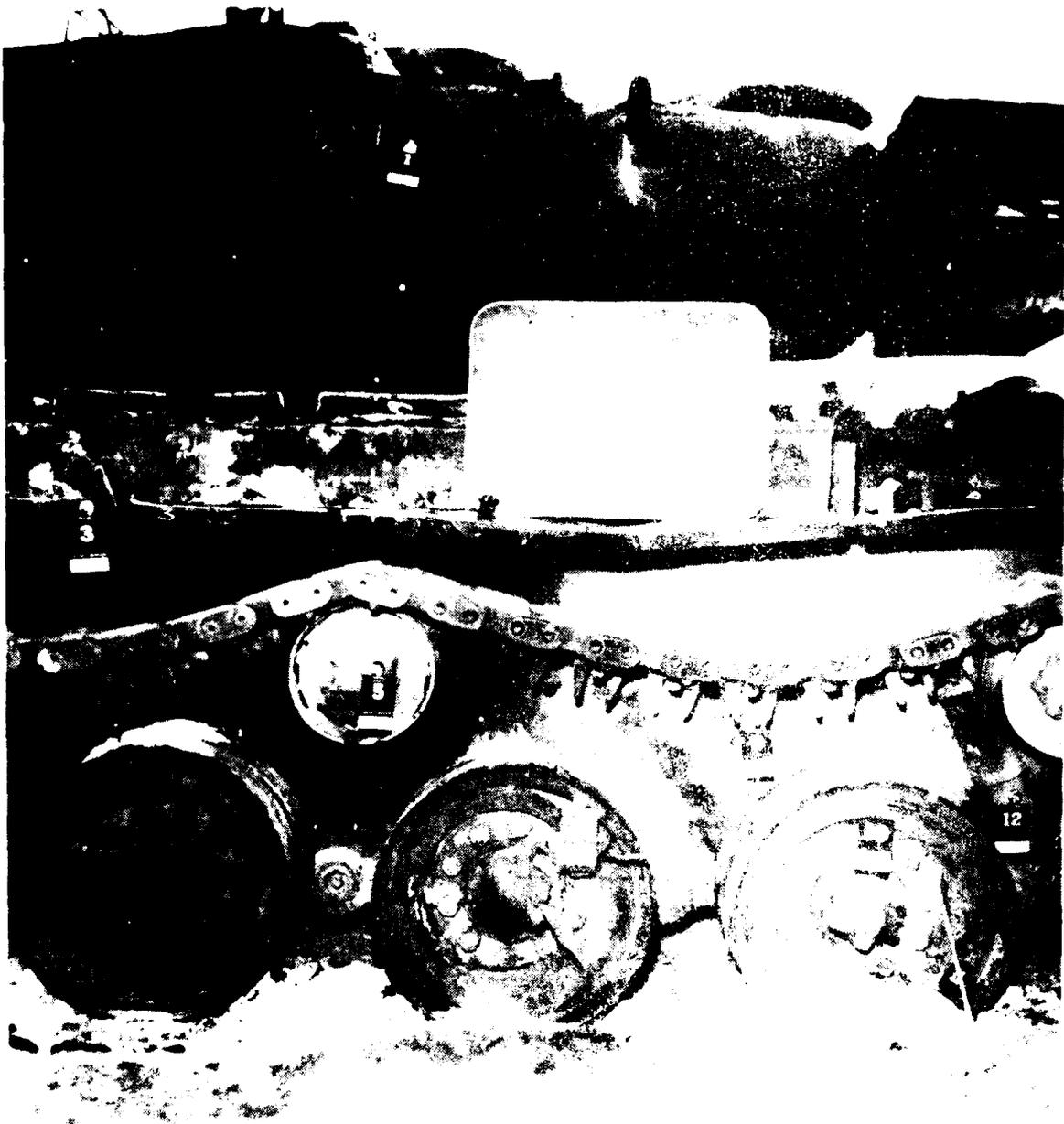


Figure 10. Front view of the vehicle.

SUMMARY AND CONCLUSIONS

On 19 September, 1979 at Nellis AFB, Nevada, the Combat Damage Assessment Team (CDAT) conducted firings of the A-10/GAU-8 weapon system against an array of 10 tanks simulating a Soviet tank company deployed for an attack. The purpose of the firing test was to evaluate the effects of Aerojet Lot Number AJD 79A181-001 30mm API anti-tank ammunition of the GAU-8 gun under challenging conditions of engagement for the A-10/GAU-8 system against realistically simulated Soviet tank formations. The CDAT used M-47 tanks stowed with main gun ammunition, diesel fuel, lubricating oil, and crew manikins to simulate the Soviet tanks. The pilot of the A-10 aircraft used in the firings conducted his attacks at low altitudes and low dive angles which simulated attack below the altitude of the effective engagement for opposing air defense systems using acquisition and fire control radar.

The firing test can be summarized in terms of the following data which were collected and/or extracted from the firings:

Aircraft Parameters

1. Open-fire Speed (average)-----540 ft/sec
2. Altitude-----427 feet
3. Dive Angle (average)-----3.3 degrees
4. Open-fire Slant Range (average)-----3658 feet
5. Burst Length/Rounds (averages)-----2.01 sec/135
6. Number Passes (primary)-----10
7. Target Aspects (predominantly)-----left side

Weapon Effects

1. Rounds Fired-----1349
2. Impacts----- 243
3. Ricochets (off ground)-- 51
4. Direct Impacts----- 192
5. Perforations----- 42

Target Damage

1. K-Kills-----3
2. M+F-Kills-----2
3. M-Kills-----3
4. F-Kills-----0
5. Light damage--1

These data and the more detailed base from which they were extracted can be arranged into measures of effectiveness for the A-10/GAU-8 system under conditions similar to those in the firing test, i.e., empirical combat simulation. The following values of effectiveness are based on the firing test on 19 September, 1979.

Measures of Effectiveness

Accuracy Related Ratio:

$$\frac{\text{Total Impacts}}{\text{Rounds Fired}} = 0.18$$

$$\frac{\text{Direct Impacts}}{\text{Rounds Fired}} = 0.14$$

Lethality Related Ratio:

$$\frac{\text{Perforations}}{\text{Total Impacts}} = 0.17$$

$$\frac{\text{Perforations}}{\text{Direct Impacts}} = 0.22$$

Weapon System Effectiveness Ratio

$$\frac{\text{Tanks Immobilized}}{\text{Passes}} = 0.80$$

$$\frac{\text{Tanks K-Killed}}{\text{Passes}} = 0.30$$

The ten target tanks were attacked predominately from the left side and suffered the damage shown in Table I and Table A-1.

The data and measures summarized above, and other data contained in this report, support several conclusions:

1. The A-10/GAU-8 weapon system in realistic simulation of combat is capable of inflicting catastrophic kills on M-47 and similarly protected main battle tanks, e.g., Soviet T-55 and T-62 tanks. The system is also capable of inflicting M- and F- kills on the same types of main battle tanks.
2. The weapon system, in low-level attacks, can perforate the side surfaces of the hulls and turrets of M-47 and similiarly protected main battle tanks. The perforating projectiles retain enough energy to ignite diesel fuel, cause crew casualties, and penetrate into engine and transmission components.
3. The weapon system is an effective killing agent against the side surfaces of M-47 and similar tanks when firing moderate to long bursts of 1.4 to 3.7 seconds containing 70 to 258 rounds.

APPENDIX A

Graphical and Summary Information

Table A-I contains a summary of the results of Mission 20 of 19 September, 1979. Table A-II contains a summary of damage assessment based on perforation locations. Table A-III contains a summary of aircraft attack parameters. Figure A-1 depicts aircraft attack aspect by pilot as a function of open-fire range.

TABLE A-I. Array 20 Results Summary
(19 September 1979)

Target Tank No.	Damage Assessment* (M%) (F%) (K%)	All Target Impacts	Direct Impacts	Rounds Fired	Total Perforations
47	100 100 ---	25	23	92	3
48	100 --- ---	9	8	129	3
4	90 95 ---	24	18	137	5
41	100 100 ---	40	33	126	4
7	100 20 ---	31	24	258	3
27	--- --- 100	24	19	70	8
29	--- --- 100	28	22	126	5
33	10 30 ---	28	20	113	5
31	100 95 ---	22	16	137	2
20	--- --- 100	12	9	161	4
TOTALS:		243	192	1349	42

*K = Catastrophic Kill; M = Mobility Kill; F = Firepower Kill

TABLE A-II. Array 20 Perforation Location Summary
(19 September 1979)

Target Tank	Damage Assessment*		Turret Perforations (Fighting Compt)	Hull Perforations		Total Perforations
	(M%)	(F%)		Fighting Compt	Drivers Engine Compt	
47	100	100	3	0	0	3
48	100	---	0	0	3	3
4	90	95	4	1	0	5
41	100	100	1	0	3	4
7	100	20	1	1	1	3
27	---	---	4	0	4	8
29	---	---	2	0	1	5
33	10	30	1	2	1	5
31	100	95	1	0	1	2
20	---	---	1	0	3	4
TOTALS:			18	4	3	42

*K = Catastrophic Kill; M = Mobility Kill; F = Firepower Kill

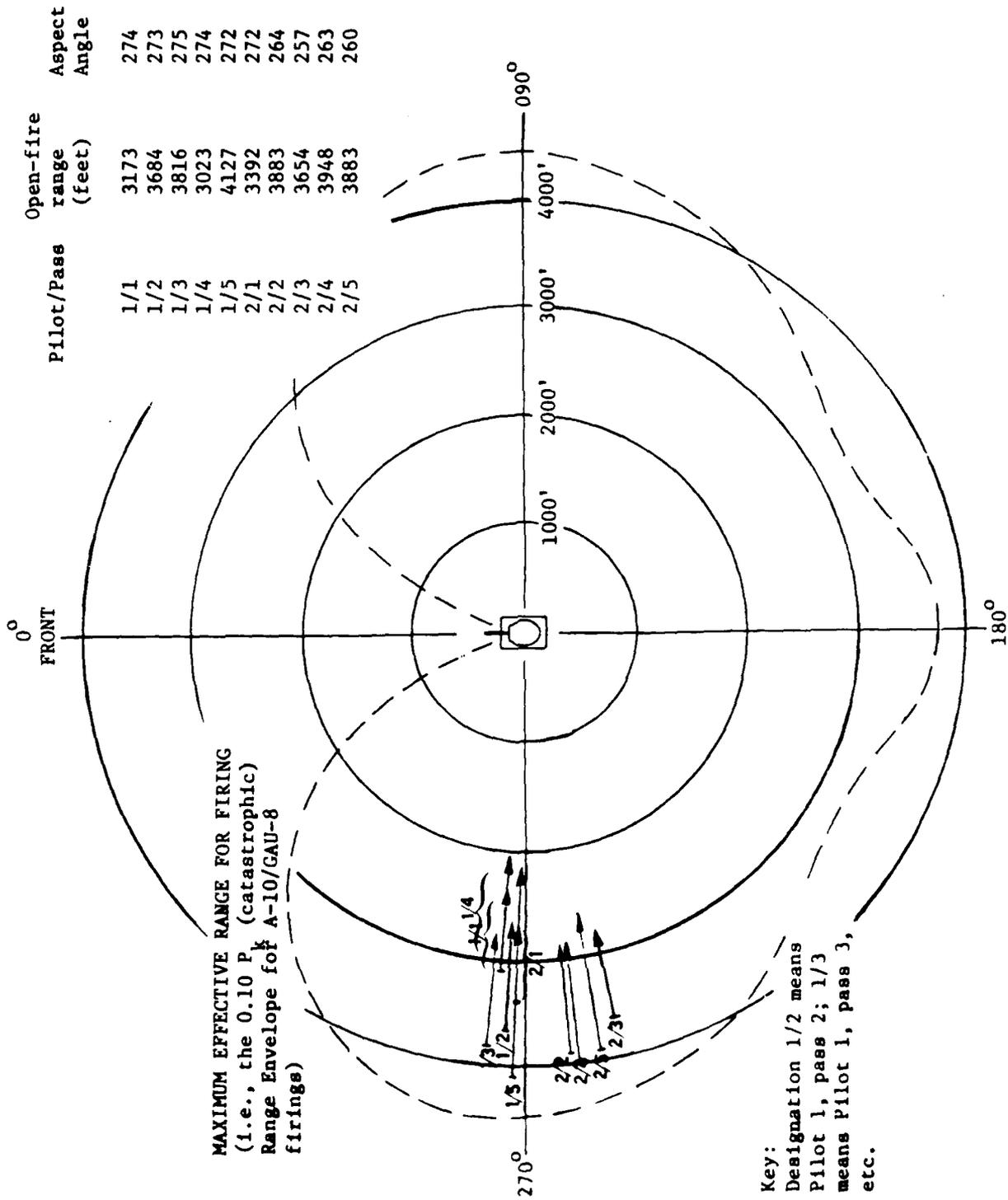


FIGURE A-1. Aircraft Attack Aspect.

TABLE A-III. Array 20 Aircraft Attack Parameters
(19 September 1979)

Acft Pass	Tank No.	Open Fire Slant Rng (feet)	Dive Angle Open/Cease (degrees)	Altitude (feet)	Velocity Open/Cease (ft/sec)	Burst Length (seconds)	Source
1/1	47	3173	-1/-2	313	573/569	1.40	HUD
		2585	-4/-4	192	579/573	1.41	TSPI
1/2	48	3684	-2/-2	243	537/535	1.92	HUD
		2777	-6/-4	251	578/573	1.06	TSPI
1/3	4	3816	-2/-1	363	532/517	2.04	HUD
		2829	-5/-4	239	544/537	1.79	TSPI
1/4	41	3023	-3/-2	353	540/542	1.88	HUD
		3085	-8/-7	369	539/527	1.82	TSPI
1/5	7	4127	-3/ 0	388	532/513	3.77	HUD
		2831	-5/-3	234	537/532	1.94	TSPI
2/1	27	3392	-2/-2	453	583/579	1.08	HUD
		2863	-8/-7	341	521/513	1.59	TSPI
2/2	29	3883	-5/-5	563	539/535	1.88	HUD
		2741	-5/-4	247	547/538	1.81	TSPI
2/3	33	3654	-5/-5	513	503/500	1.69	HUD
		3294	-8/-7	402	532/549	2.04	TSPI
2/4	31	3948	-5/-5	613	535/534	2.04	HUD
		3400	-5/-3	312	534/524	3.70	TSPI
2/5	20	3883	-5/-5	463	534/534	2.38	HUD
		3161	-7/-6	352	538/518.6	2.32	TSPI
HUD Averages:		3658	-3.3	427	540/536	2.01	

NOMINAL HUD FILM TOLERANCES:

SLANT RANGES: PLUS ZERO MINUS 150 FEET
 DIVE ANGLES: PLUS 0.5 MINUS 0.5 DEGREE
 VELOCITIES: PLUS 8.4 MINUS 8.4 FEET PER SECOND
 BURST TIMES: PLUS 0.0 MINUS 0.021 SECOND

NOTE: This table presents attack parameter data from two sources. Due to poor TSPI camera location, HUD film data is considered the most reliable.

APPENDIX B

DEFINITIONS

The terms used in this report are defined below:

IMPACT -- Any evidence of a projectile strike against any portion of the target. Ground ricochets striking the target were classified as "impacts".

PERFORATION -- Any rupture of the armored envelope caused by an impacting projectile which results in a complete rupture of an armored surface by the projectile or spall fragments. A perforation can occur only when the armor is impacted. The word "Perforation" was deliberately selected to avoid the ambiguities which may occur through use of the word "penetration". Behind-the-plate effects may or may not result from a perforation.

HIT -- Any impact not classified as a perforation.

MOBILITY KILL (M-KILL) -- Loss of tactical mobility resulting from damage which cannot be repaired by the crew on the battlefield. A tank is considered to have sustained a 100% M-Kill when it is no longer capable of executing controlled movement on the battlefield. Mobility is DEGRADED when a tank can no longer maintain position in its formation.

FIREPOWER KILL (F-KILL) -- Loss of tactical firepower resulting from damage which cannot be repaired by the crew on the battlefield. A tank is considered to have sustained a 100% F-Kill when it is incapable of delivering controlled fire from its main armament. Firepower is DEGRADED when a tank can no longer maintain its "normal" rate-of-fire, velocity, accuracy, time to shift targets, etc.

CATASTROPHIC KILL (K-KILL) -- A tank is considered to have sustained a K-Kill when both an M-Kill and a F-Kill have occurred as the result of killing fires and explosions from ignited fuel and/or ammunition. A tank which has suffered a K-Kill is considered not to be economically repairable, and, by U.S. standards, would be abandoned on the battlefield.

ATTACK ASPECT -- The angle of approach of the aircraft with respect to the orientation of the tank with zero degrees representing the front of the tank (gun forward) and 180 degrees representing the rear of the tank.

SIGNIFICANT IMPACTS -- Impacts which damage systems, components or sub-systems resulting in their destruction or partial loss of function. This type damage contributes to the assessed kill.

INSIGNIFICANT IMPACTS -- Impacts which damage non-critical structural, convenience, or accessory components and which may result in their destruction or partial loss of function, but with no impact on mobility or firepower considerations. Good maintenance practices contemplate repair or replacement of such items at the earliest opportunity consistent with accomplishment of the mission.

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