ABRAMS

CHARACTERISTICS AND DESCRIPTION BOOK M1A1 TANK

NEW EQUIPMENT TRAINING TEAM
FORT KNOX, KENTUCKY

PREFACE

This Book was prepared during early M1A1 Tank production in accordance with the requirements of the U.S. Government System Technical Support (STS) Contract DAAE07-85-C-R022, Contract Data Item DI-S-4057.

A functional and technical description of the M1A1 Tank System is provided in the following pages to help the reader better understand the function of the Tank and its components.

This is the first edition of the M1A1 Tank Characteristics and Description Book.

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The Characteristics and Description (C & D) Book provides a ready and concise description of the M1A1 Tank System and its equipment. This book is intended for use as a reference document by tank system managers, engineers, planners, and users.

The C & D Book contains the following information:

a. A description of the M1A1 Tank System including characteristics, functional block diagrams, the quantity of each major hardware item, and the drawing/installation family tree.

b. A narrative functional description of each major hardware item.

c. A photograph or silhouette of each major hardware item.

1.2 SYSTEM DEFINITION

1.2.1 General Description

The M1A1 Tank is a fully tracked, low-profile, land combat assault weapon system possessing armor protection, shoot-on-the-move capability, and a high degree of maneuverability and tactical agility. The four-man crew has the capability to engage the full spectrum of enemy ground targets with a variety of accurate point and area fire weapons.

1.2.2 Functional Areas

Functional flow block diagrams for the system illustrate the relationship between system functional areas and the system characteristics and descriptions contained in this book. The top level functional block diagram shown in figure 1-1 defines those system functional elements which must be accomplished to meet the M1A1 tank system objectives. The

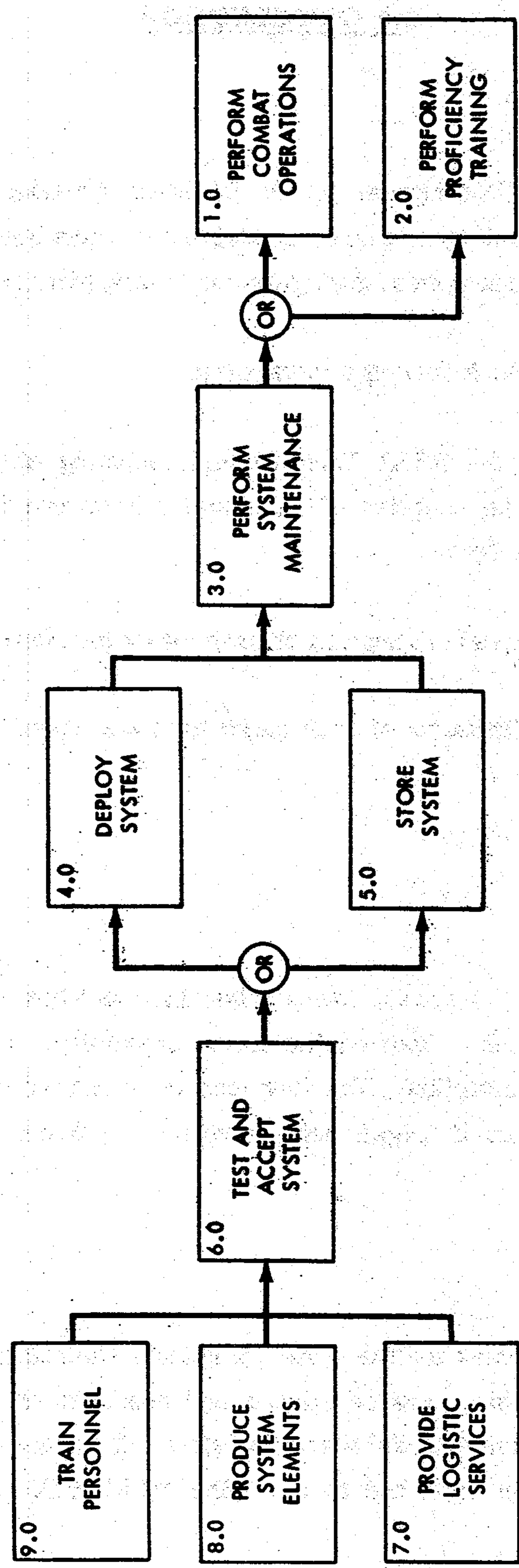


Figure 1-1. System Level Functional Diagram

second level functional block diagram shown in figure 1-2 shows the combat operations system function. The functional characteristics related to the M1A1 tank hardware elements are presented in the functional diagrams of figures 1-3 through 1-7.

1.2.3 Missions

The classical offensive, defensive, and retrograde missions of tank combat units remain in being now and into the foreseeable future. To capitalize on the effectiveness of tank units and to optimize the results of their deployment, the traditional factors of Mission, Enemy, Terrain, and Troops (METT) available must be considered in organizing the forces for combat. The commander uses the combined arms team concept and will habitually organize his forces by cross-attachment of the tank and infantry units. The improved capabilities of infantry antitank weapons and the Advanced Attack Helicopter (AAH) to defeat enemy tanks have freed the tank from its function of being the primary antitank system on the battlefield. The offensive nature of the tank can, therefore, be more fully realized since it no longer represents the primary means of antitank defense. The M1A1 Tank, utilized as the principal element in the combined arms team, will possess in a single system the essential requisites for mounted combat which consist of a high degree of tactical mobility, shoot-on-the-move capability, and protected firepower. The M1A1 Tank, complemented by other elements in the combined arms team, will be the decisive element on the battlefield.

1.2.4 Operational Concept

The M1A1 Tank will be the principal element of armor whose role on the battlefield is to defeat enemy forces, using firepower and movement. The role of the individual M1A1 Tank can best be described as the principal element in the combined arms team. It is the Tank that possesses, in a single system, the essential requisites for mounted combat, which consist of a high degree of tactical mobility and protected firepower. Within the combined arms concept, the M1A1 Tank will normally be employed as a member of a team of four tanks called a platoon which performs as an entity under the command of a platoon leader assisted by a platoon sergeant.

In the offense, The Tank will retain its classical role, spearheading the assault elements of the field Army. The Tank will be employed as a member of a combined arms force which

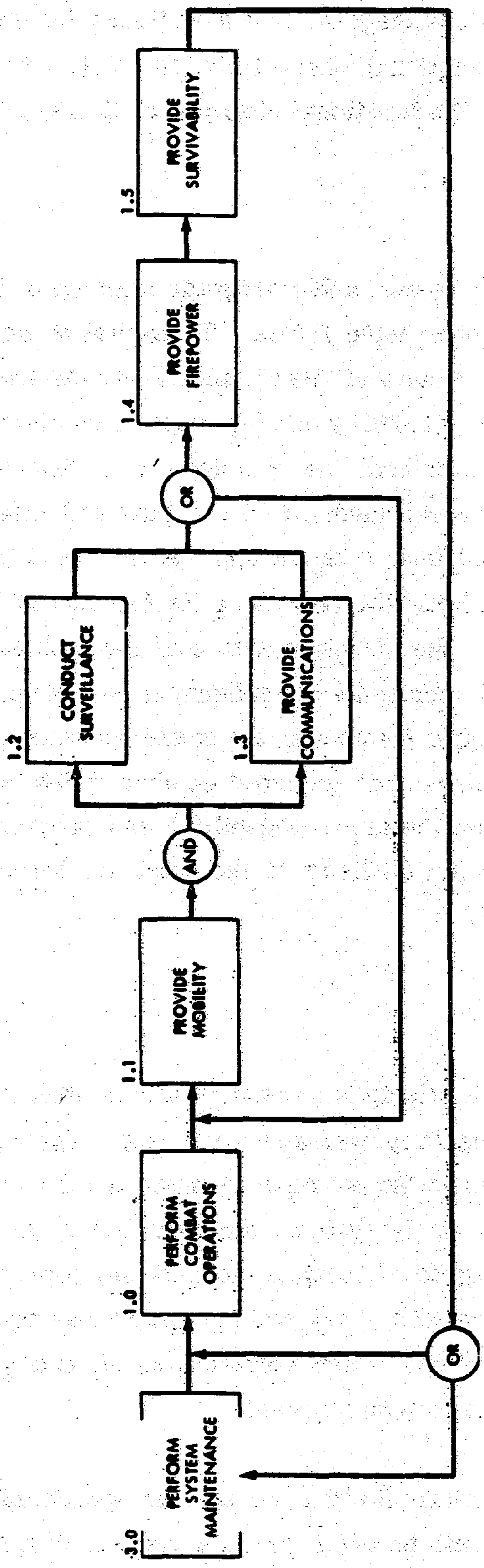


Figure 1-2. Second Level Combat Operations Functional Diagram

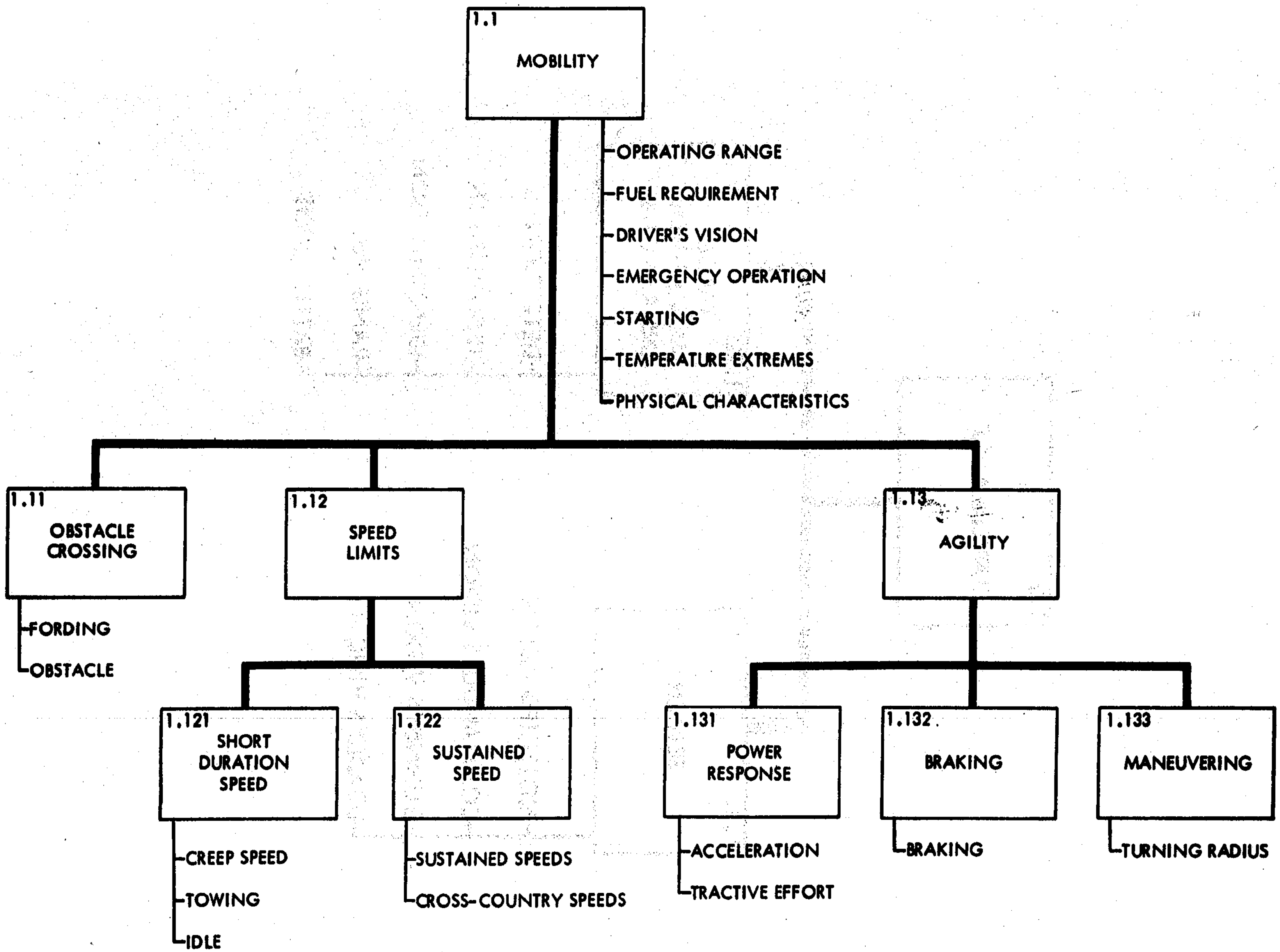


Figure 1-3. Mobility Functional Diagram

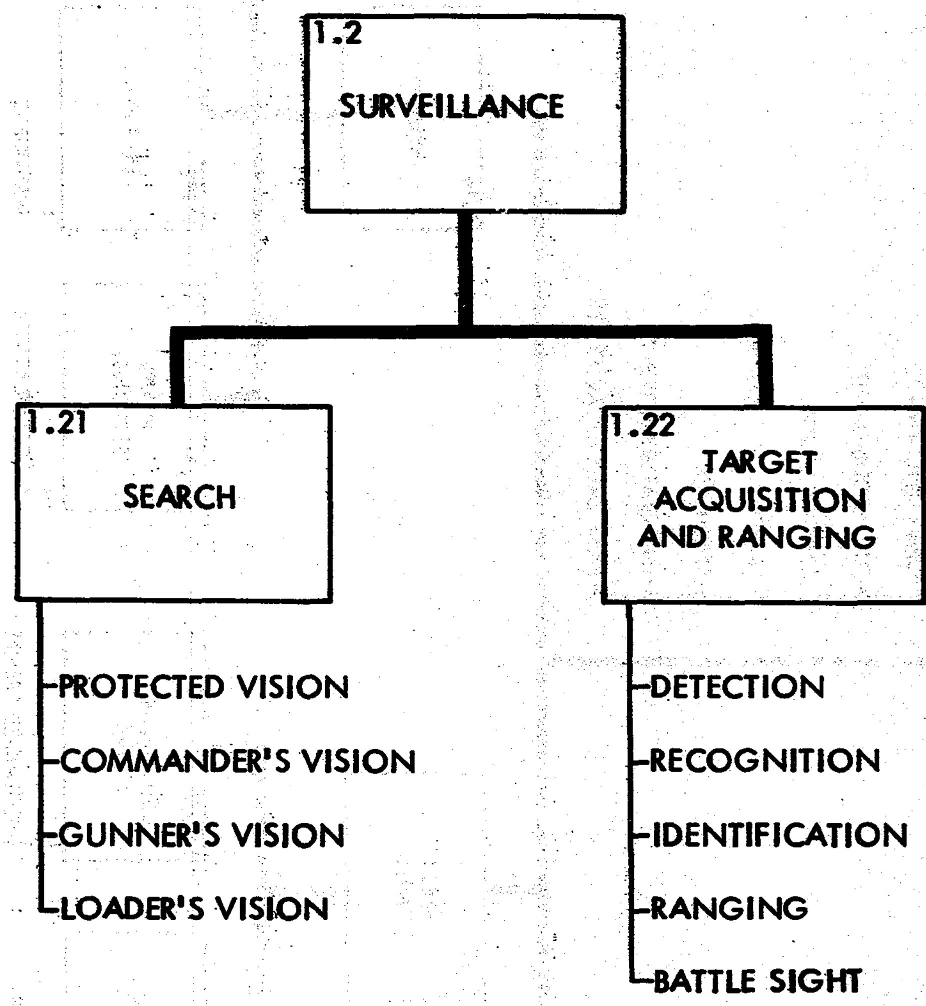


Figure 1-4. Surveillance Functional Diagram

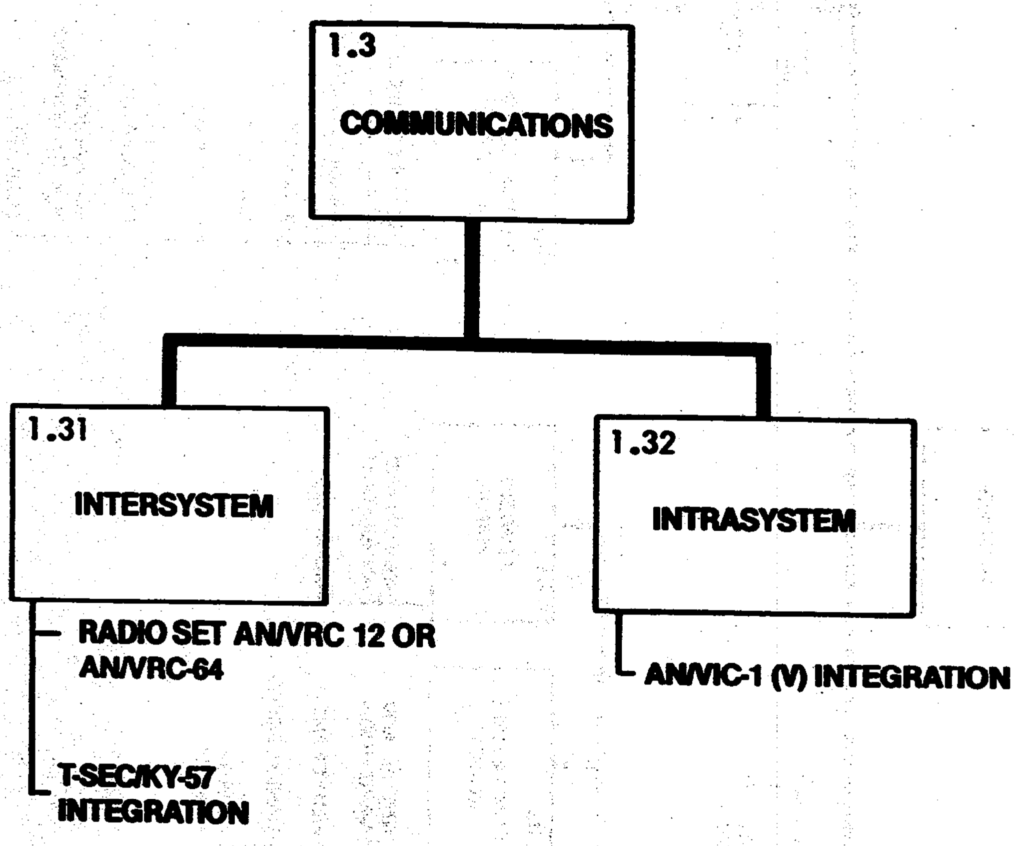


Figure 1-5. Communications Functional Diagram

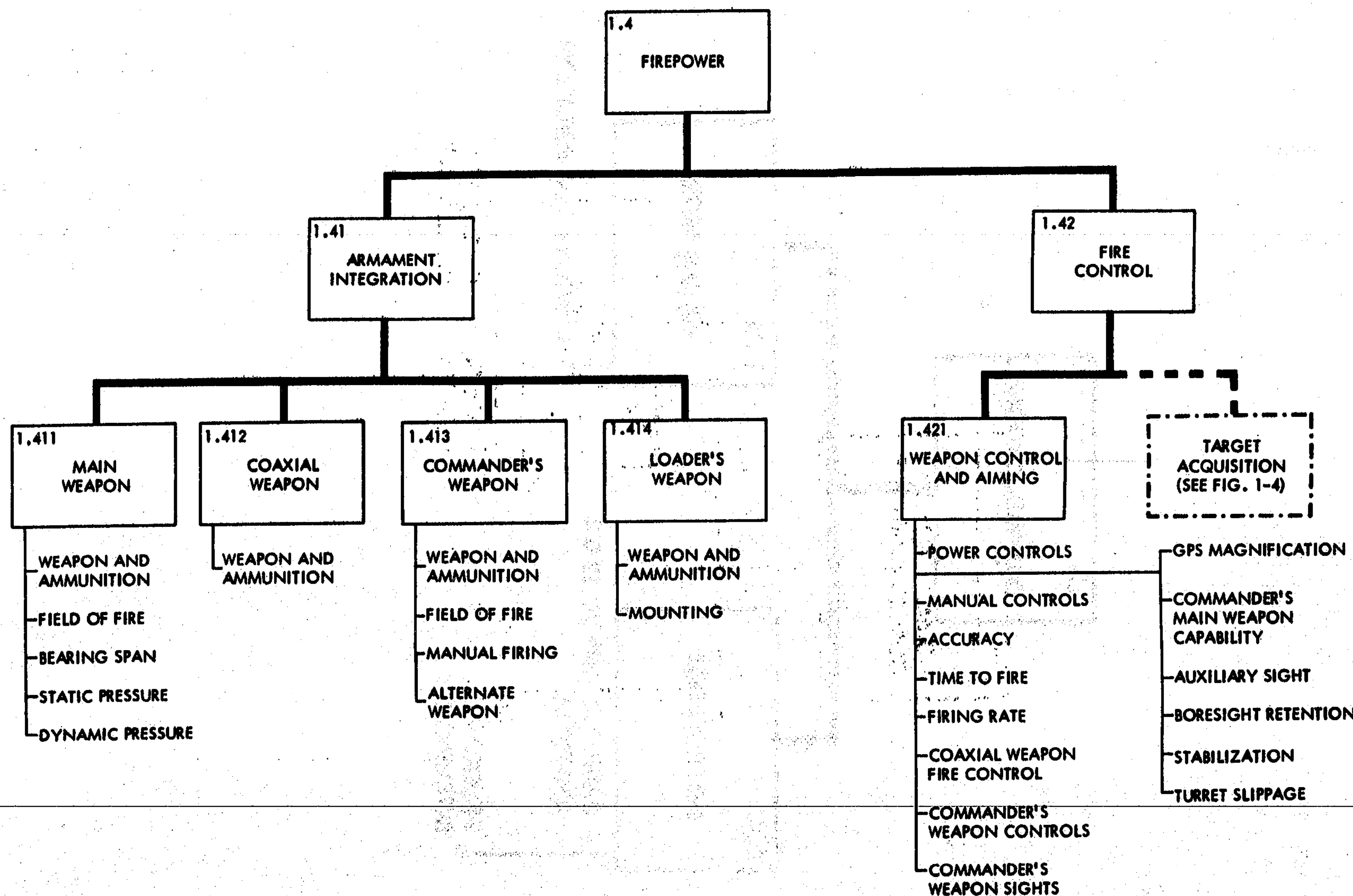


Figure 1-6. Firepower Functional Diagram

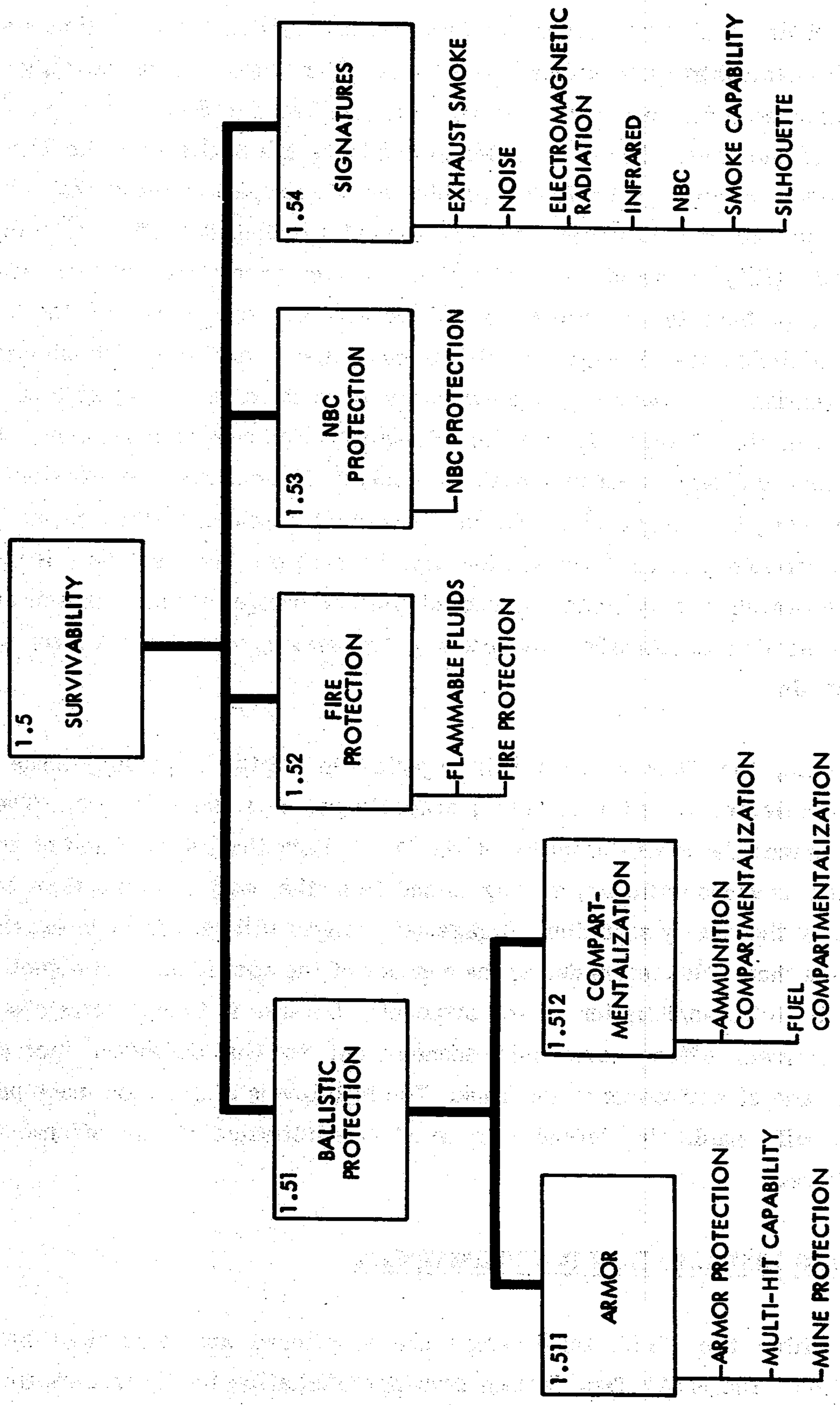


Figure 1-7. Survivability Functional Diagram

normally includes artillery, mechanized infantry, air defense, and aviation assets. The Tank remains central to the combined arms force. The primary ordnance delivery system and the combined arms force exist primarily to support the Tank in its role related to destruction of the enemy force. In order to dominate the battlefield, the Tank must be able to survive. Survival of the Tank is predicated on four basic rules of tank employment and design: utilize terrain, cover, and concealment to avoid detection; if detected, use mobility and agility to avoid being hit; if hit, armor protection must be adequate to minimize the probability of penetration; if penetrated, the design of the tank must inherently minimize the damage to critical components and explosive stowage areas, thereby increasing the probability of crew survival. With respect to these four rules, the tank platoon in the offense will use the following techniques of movement: traveling, enemy contact unlikely, platoon moves in column of sections and constant interval between sections; traveling overwatch, enemy contact possible, platoon moves in column of sections, variable interval (trail section keys its rate of movement on a lead section); bounding overwatch, enemy contact expected, platoon uses either alternate or successive bounds, one section continually overwatching the movement of the other, movement keyed to terrain.

In the defense, the Tank Platoon will organize in depth, employing three or more positions, preselected to optimize cover, concealment, and fields of fire. The platoon defense optimizes the mobility/agility of the M1A1 Tank through attrition of enemy fire by firing from covered positions, moving to and from the battlefield positions by section as dictated by the enemy situation. Engagement ranges will vary from in excess of 3000 meters to less than 1000 meters during the conduct of the operation. The objective of the defense is the total annihilation of the attacker. Defense is tied to terrain only in the sense that terrain offers cover and concealment to the defender, increasing the survivability and effectiveness of the Tank. The high levels of attrition made possible by the defense will enable the defender to wrest the initiative of the offense from the attacking force.

1.3 DRAWING/INSTALLATION DOCUMENTATION

Interfaces within the M1A1 tank design are monitored and controlled by drawing documentation. The M1A1 Tank System drawing/installation family tree shown in figure 1-8 depicts the major assembly drawings (turret and chassis), the components, and the subcontractor interfaces.

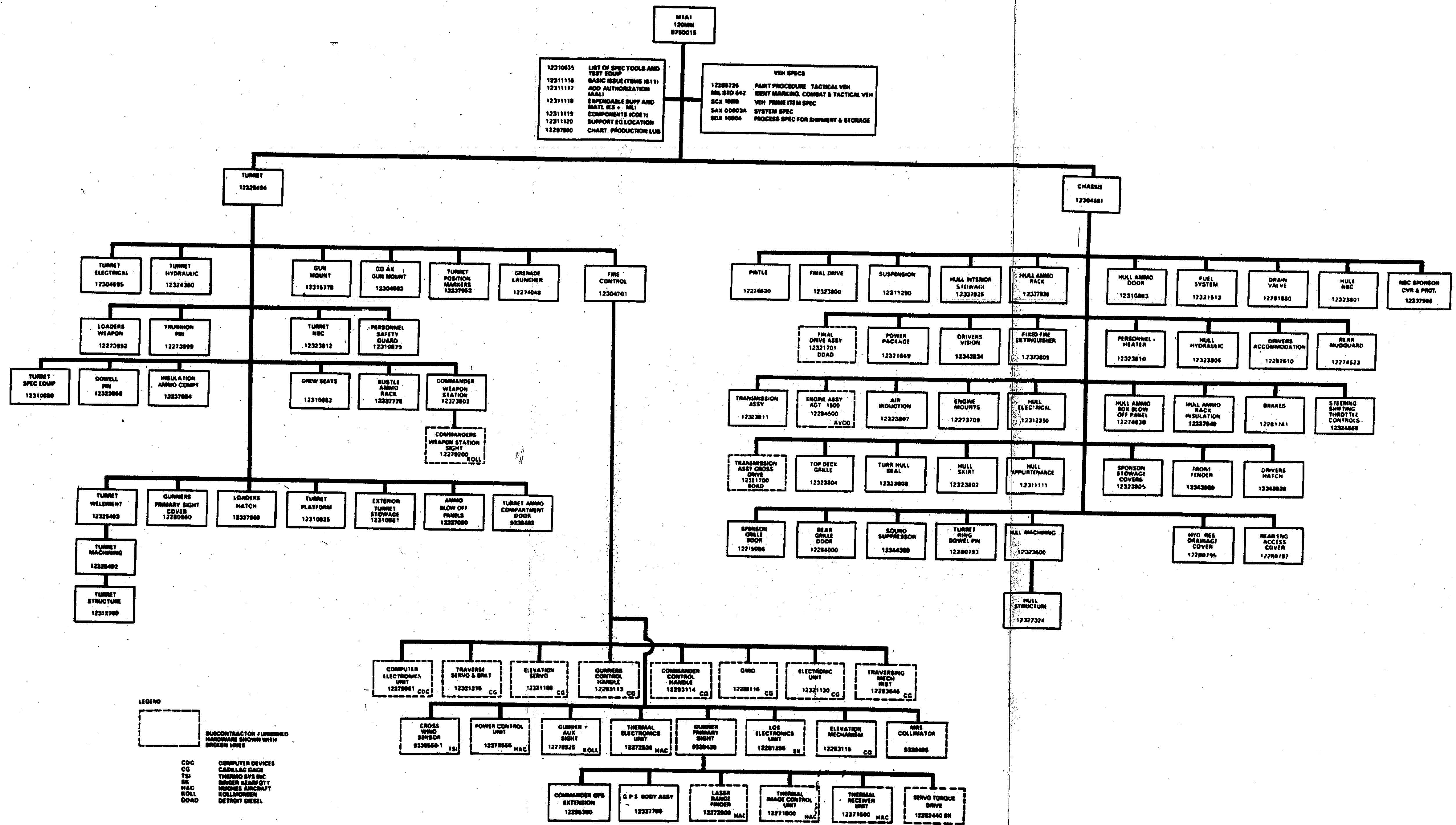


Figure 1-8. Drawing/Installation Family Tree

2.0 SYSTEM CHARACTERISTICS

2.1 SALIENT FEATURES

The M1A1 Tank is illustrated in figures 2-1 through 2-6. Figure 2-7 depicts the external features of the Tank. The Tank is a fully tracked, armored, land combat vehicle operated by a four-man crew consisting of the commander, gunner, loader, and driver. It is powered by a 1500 horsepower turbine engine, an automatic transmission, and two final drives. Transmission output is through identical left and right final drives to the track drive hub and sprocket assemblies. The governed engine speed allows a vehicle top speed of 41.5 mph on level hard surface roads.

The suspension system with seven roadarms and torsion bars per side, is selectively damped to provide tank mobility over cross-country terrain at speeds up to 30 miles per hour.

The 120mm M256 gun, mounted on a traversable turret, is used against fortifications, moving or stationary armored vehicles, and enemy troops.

The secondary weapons consist of two 7.62mm, M240 machineguns and a .50 caliber, M2 machinegun. One 7.62mm, M240 machinegun is coaxially mounted on the right side of the main gun mount and is intended for use against troop targets. The other 7.62mm, M240 machinegun is skate mounted at the loader's station and is used against troops and aircraft. The .50 caliber, M2 machinegun mounted at the Commander's Weapon Station (CWS) is used against troops, lightly armored vehicles, and aircraft.

Nuclear, biological, and chemical (NBC) protection is provided on an individual (ventilated face piece and protective overgarment) and collective basis by maintaining the crew compartment above ambient pressure and by providing filtered air. Crew protection against heat stress is also provided by cooling the filterd air and passing it through each crewman's air cooled vest.

The NBC system uses bleed-air from the engine which is passed through an air cycle pack where it is cooled by a heat-exchanger and expansion turbine. The cooled air then goes to the NBC composite filters where contaminants are removed. The cooled air is then circulated to the each crew members ventilated face piece and air cooled vest.

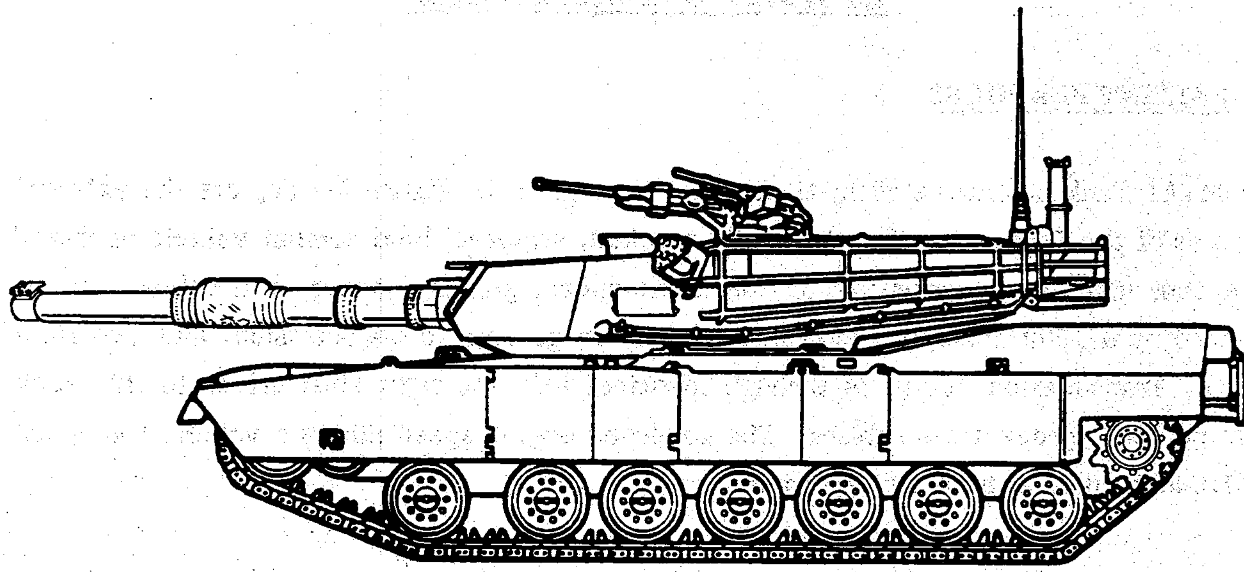


Figure 2-1. M1A1 Tank (Left Side View)

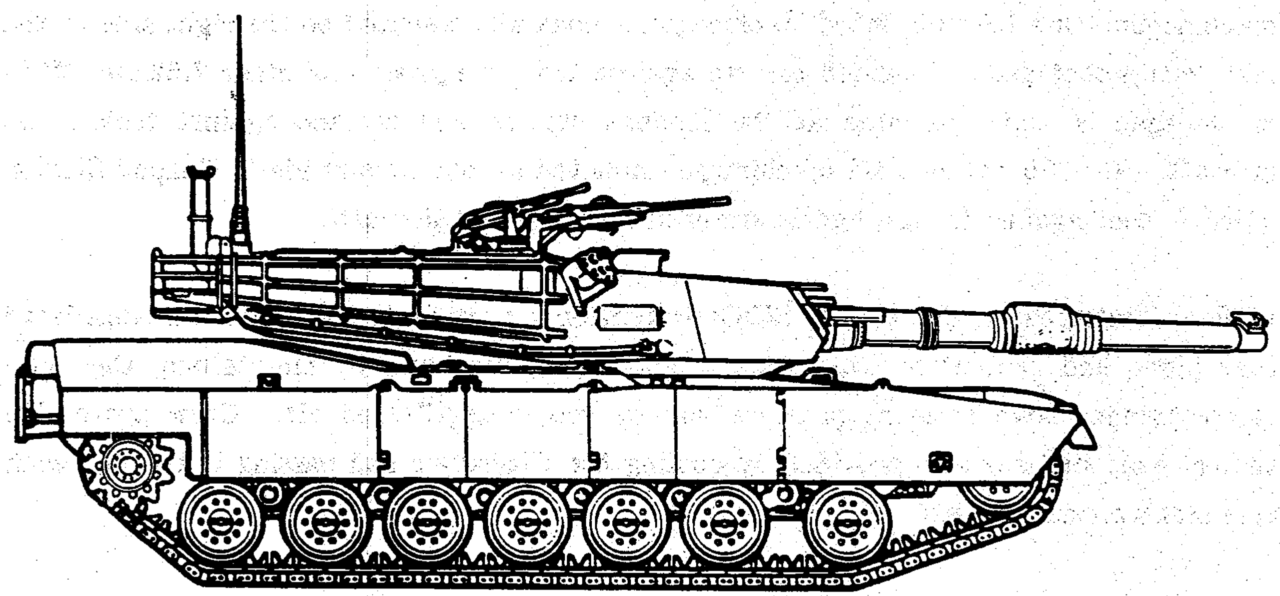


Figure 2-2. M1A1 Tank (Right Side View)

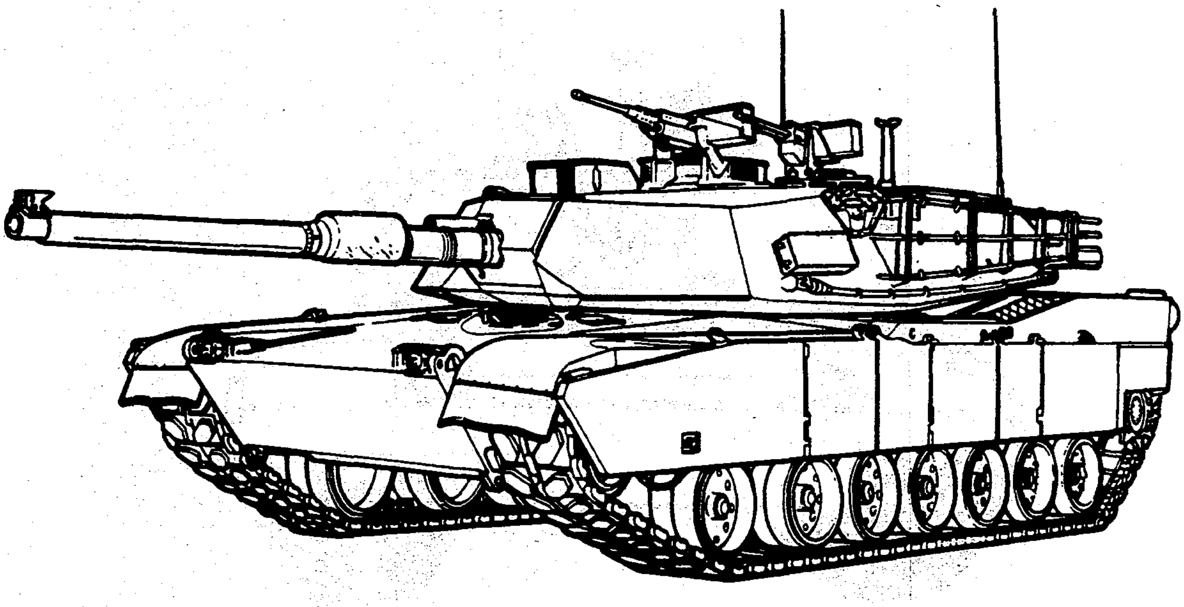


Figure 2-3. M1A1 Tank (3/4 Left Front View)

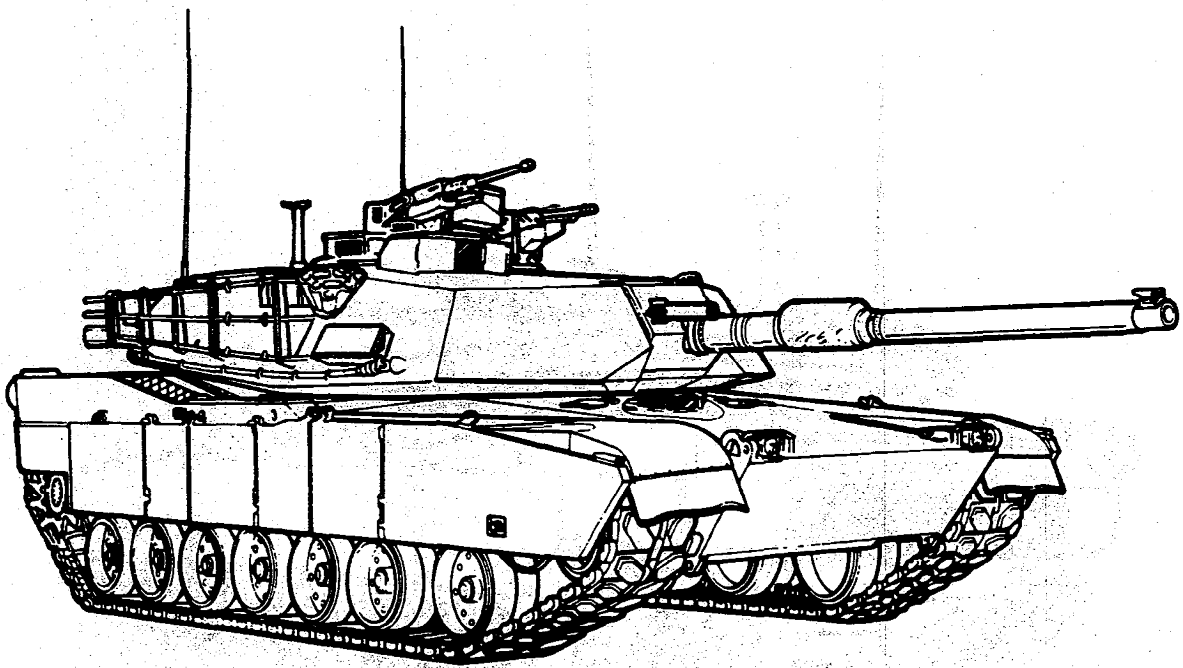


Figure 2-4. M1A1 Tank (3/4 Right Front View)

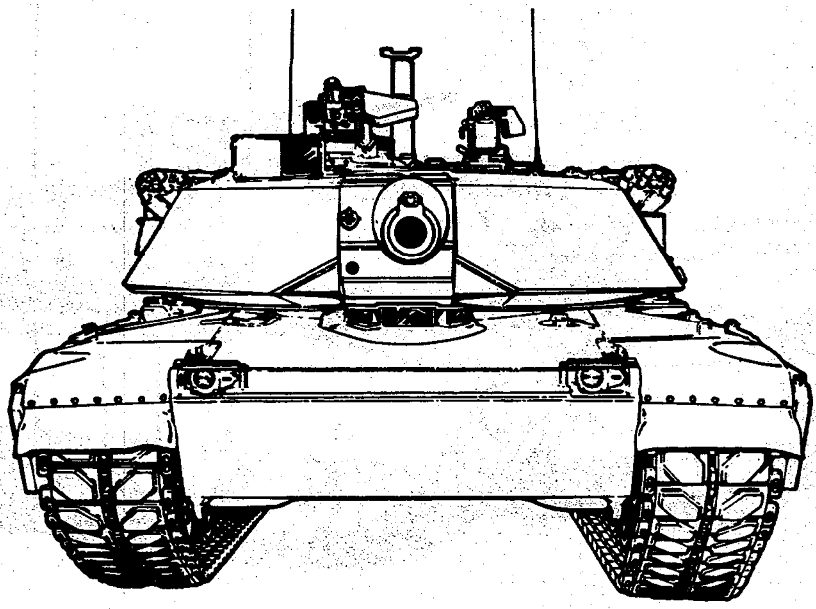


Figure 2-5. M1A1 Tank (Front View)

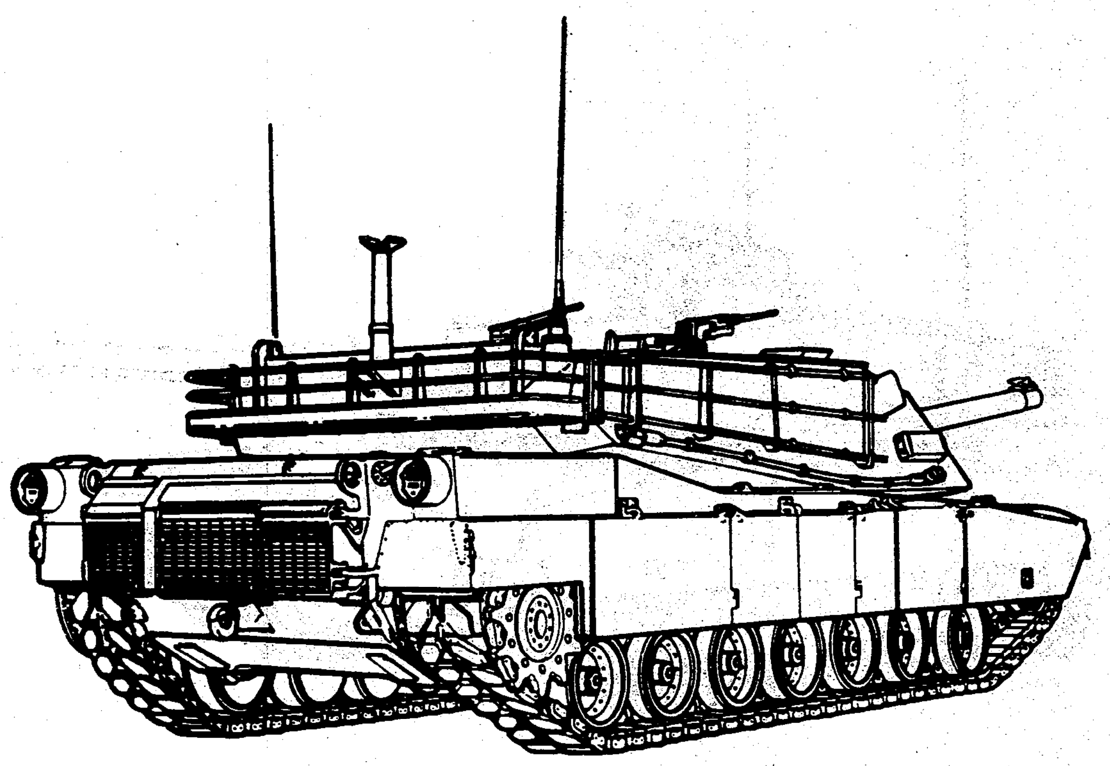


Figure 2-6. M1A1 Tank (3/4 Right Rear View)

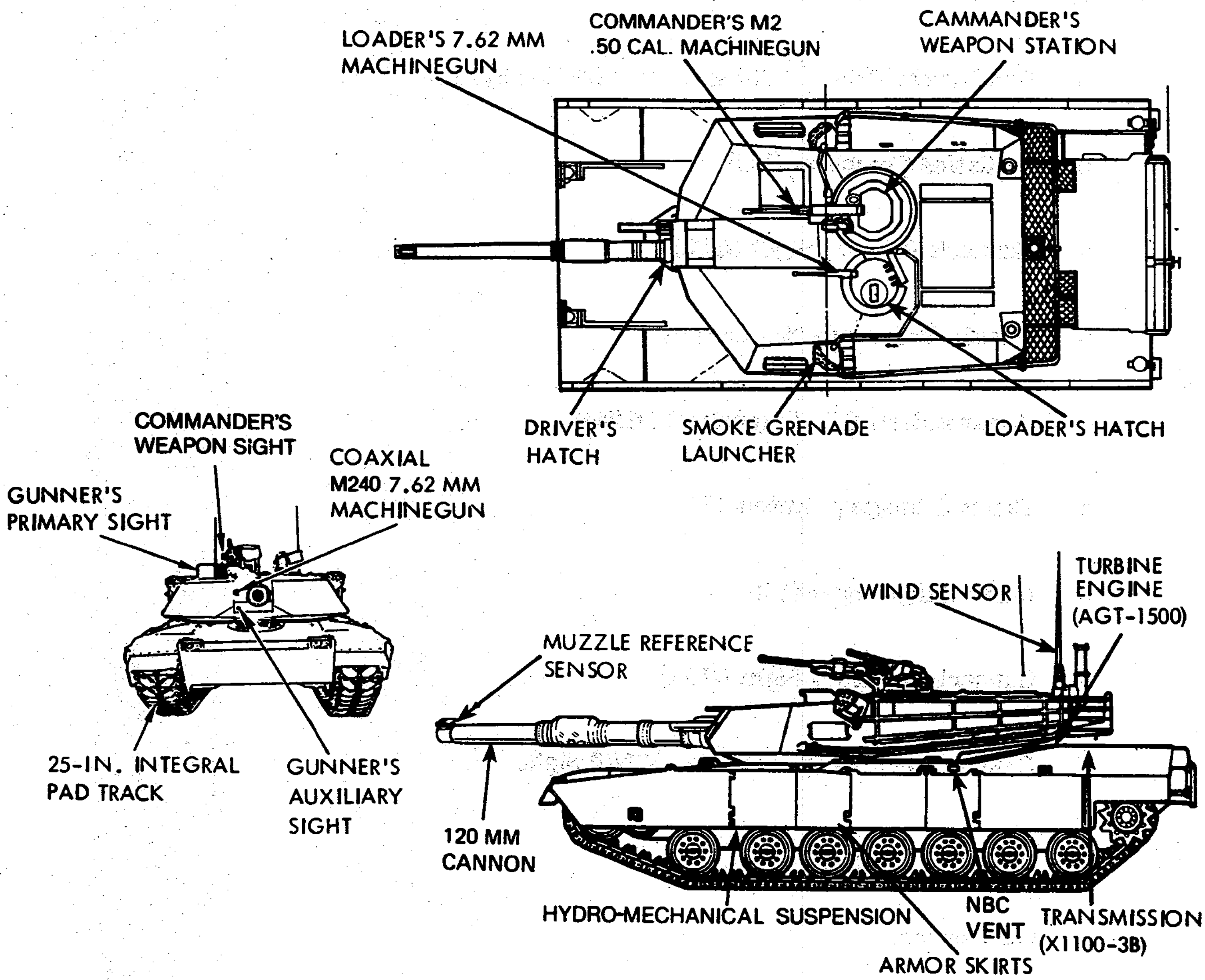


Figure 2-7. M1A1 Tank External Features

An AN/VDR-2 radiac is located in the crew compartment to detect low threshold gamma radiation. Decontamination capability is provided by three ABC M11 DS-2 decontamination devices (one stowed in the crew compartment and one in each turret cargo stowage box).

Principal elements of the fire control system are as follows:

- Gun/Turret Drive (GTD) and Stabilization System
- Ballistics Computer (BC)
- Gunner's Primary Sight (GPS)
- Muzzle Reference Sensor (MRS)
- Commander's GPS Extension (CGPSE)
- Thermal Imaging System (TIS)
- Laser Rangefinder (LR)
- Gunner's Auxiliary Sight (GAS)
- Commander's Weapon Station (CWS) Sight
- Crosswind Sensor
- Cant Sensor

The hydraulically powered Gun/Turret Drive (G/TD) and Stabilization System provides for gun stabilization in elevation and turret stabilization in azimuth. The gun elevation and depression is achieved by a hydraulic cylinder, and the gun/turret traverse is accomplished through a hydraulic motor and gearbox combination. Control of the system is achieved electronically.

The Line of Sight (LOS) System and Gunner's Primary Sight (GPS) together provide for line of sight stabilization in elevation and reticle stabilization in azimuth.

The digital Ballistics Computer (BC) permits accommodation of changes in ammunition and/or ballistics data. It also provides for automatic selection of multiple lead filters so accurate lead corrections can be determined for moving targets. In addition, although functioning of the fire control system is continuously monitored by the computer, the computer performs fire control system built-in test functions by direct interrogation to determine the malfunctioning element. Fire control electronic units are grouped and mounted in one rack for ready access and ease of maintenance.

The fire control system Gunner's Primary Sight (GPS) provides line-of-sight stabilization in elevation, thereby achieving main gun aim retention to ensure hit probabilities that meet system requirements.

The Muzzle Reference Sensor is incorporated into the fire control system by an optical wedge in the GPS which permits the optical axis of the GPS to align to the reticle collimator mounted on the end of the gun tube. This allows the boresight position to be adjusted as a function of gun tube bend.

Optical requirements of the fire control system are improved by integrating the laser into the GPS. The primary aiming reticle and laser beam are combined in the laser transceiver to ensure accurate alignment. The GPS optical relay to the commander's station provides a full day and night vision fire control capability for the commander. A main gun backup aiming capability is provided by the Gunner's Auxiliary Sight (GAS).

Human factors have been optimized in the design of crew stations. Simple controls are grouped so that crew operations are performed at maximum efficiency.

Weld-fabricated, rolled, homogenous armor, combined with hull and turret armor assemblies, provide frontal armor protection. The turret front and sides, including the gun shield, are protected against the specified large caliber threats. Large caliber protection for the hull front is provided by an armor assembly across the entire hull width with high obliquity upper and lower glacis plates. Hull side protection consists of armored skirts and structure. The rear hull structure and the rear grille doors give protection from small arms fire.

Crew and tank survivability are enhanced by compartmentalized stowage of fuel and ammunition, by minimizing visual and noise signatures, and by nuclear hardening electronic components. Compartmentalized stowage of fuel and ammunition reduces the likelihood of a significant event (secondary fires or explosions) which may destroy the tank or injure the crew. Minimizing visual and noise signatures reduces the probability of being detected and hit by mortars, rockets, or missiles. Nuclear hardening ensures that the tank's electronic subsystems will remain operable after a nuclear explosion which will generate various effects, including: shock, thermal, electromagnetic pulse (EMP) and transient radiation (gamma rays, neutrons, etc).

2.2 SYSTEM CHARACTERISTICS SUMMARY

2.2.1 Physical Characteristics

Weight, Combat Loaded (less kits) - - - - - - - - - - - - - - - - - -	63.2 tons
Ground Clearance (center portion of hull structure) - - - - - - - -	19 in.
Ground Clearance (other portions of hull structure) - - - - - - - -	17 in.
Ground Pressure -	14.0 psi
Height (ground to turret roof) - - - - - - - - - - - - - - - - - - -	96 in.
Maximum Tank Height (overall) - - - - - - - - - - - - - - - - - - -	113.6 in.
Maximum Tank Height (reducible overall) - - - - - - - - - - - - -	103.5 in.
Length (overall main weapon forward) - - - - - - - - - - - - - - -	386.94 in.
Length (overall main weapon rearward) - - - - - - - - - - - - - -	355.64 in.
Width (overall) -	144 in.
Width (reducible) -	137 in.
Dimensions -	(figures 2-8 thru 2-12)
Vehicle Center of Gravity	
(X) Longitudinal (forward of final drive centerline) - -	126.3 in.
(Y) Lateral (positive, right on vehicle centerline) - -	1.2 in.
(Z) Vertical (above ground line) - - - - - - - - - - -	52.1 in.
Vehicle Frontal Area -	75.9 ft^2
Vehicle Side Area -	162 ft^2
Vehicle Top Area -	311 ft^2

2.2.2 Performance

Gross Horsepower-to-Weight Ratio (combat loaded tank) - - - - -	23.8 hp/ton
Maximum Forward Speed (hard level surface) - - - - - - - - - - -	41.5 mph
Sustained Speed (60 percent grade) - - - - - - - - - - - - - - - -	NBC on 4.0 mph NBC off 4.1 mph
Cross-Country Speed -	up to 30 mph
Acceleration (forward direction, time from 0 to 20 mph, dry and level surface roads) -	NBC on 7.1 sec NBC off 6.8 sec

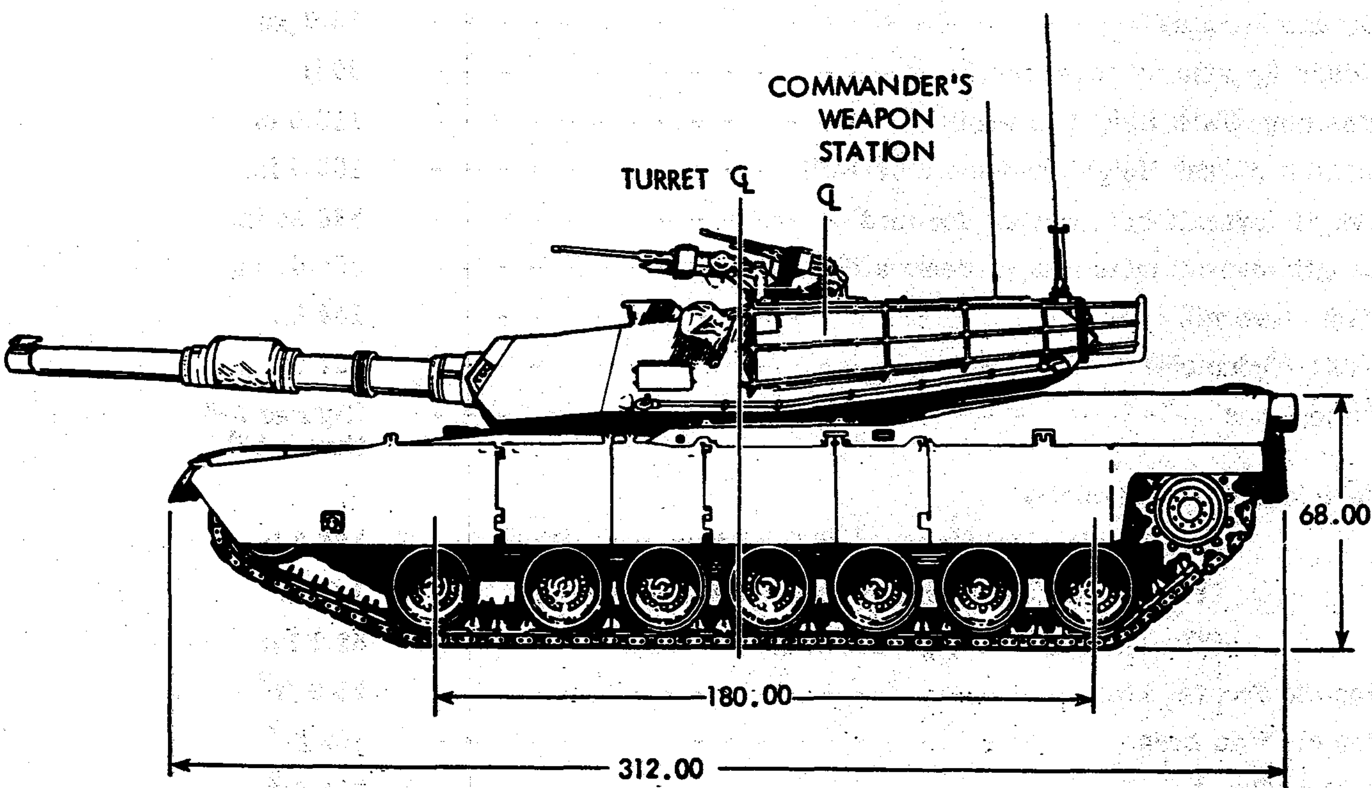


Figure 2-8. M1A1 Tank Dimensional Characteristics (Left Side)

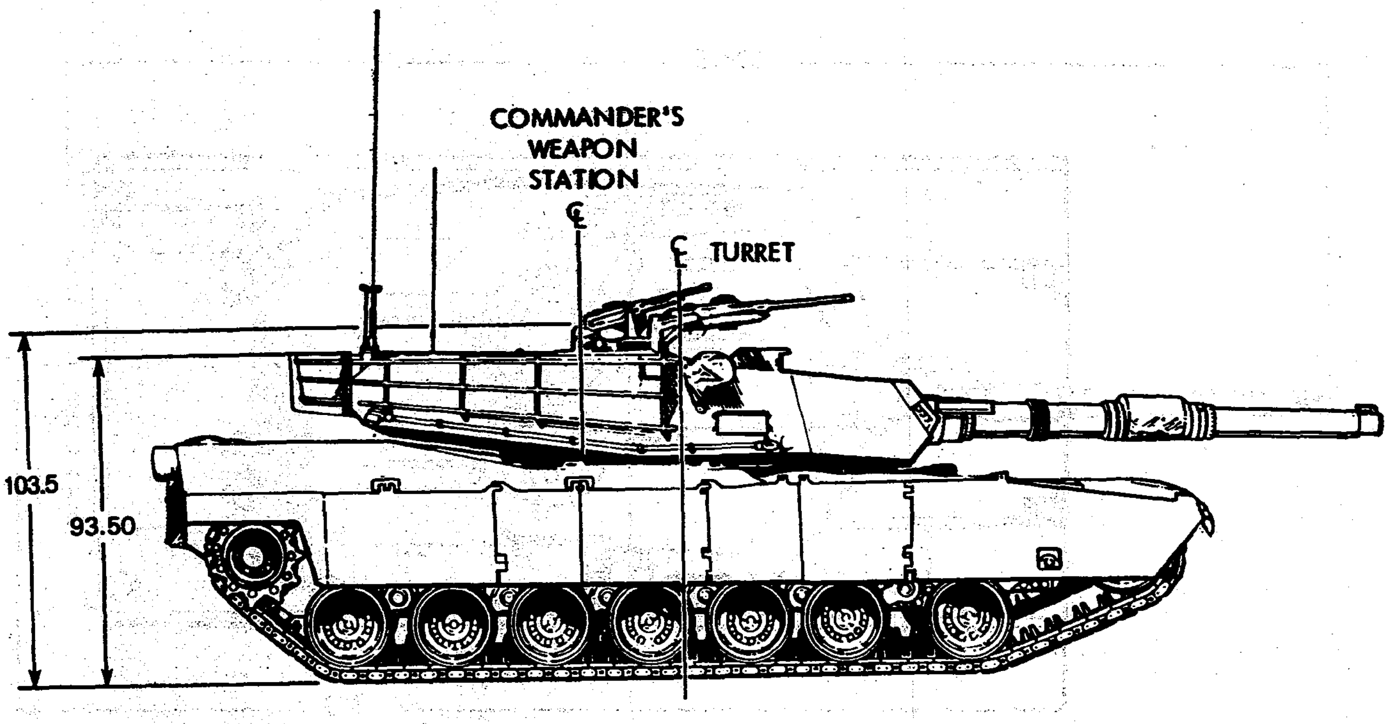


Figure 2-9. M1A1 Tank Dimensional Characteristics (Right Side)

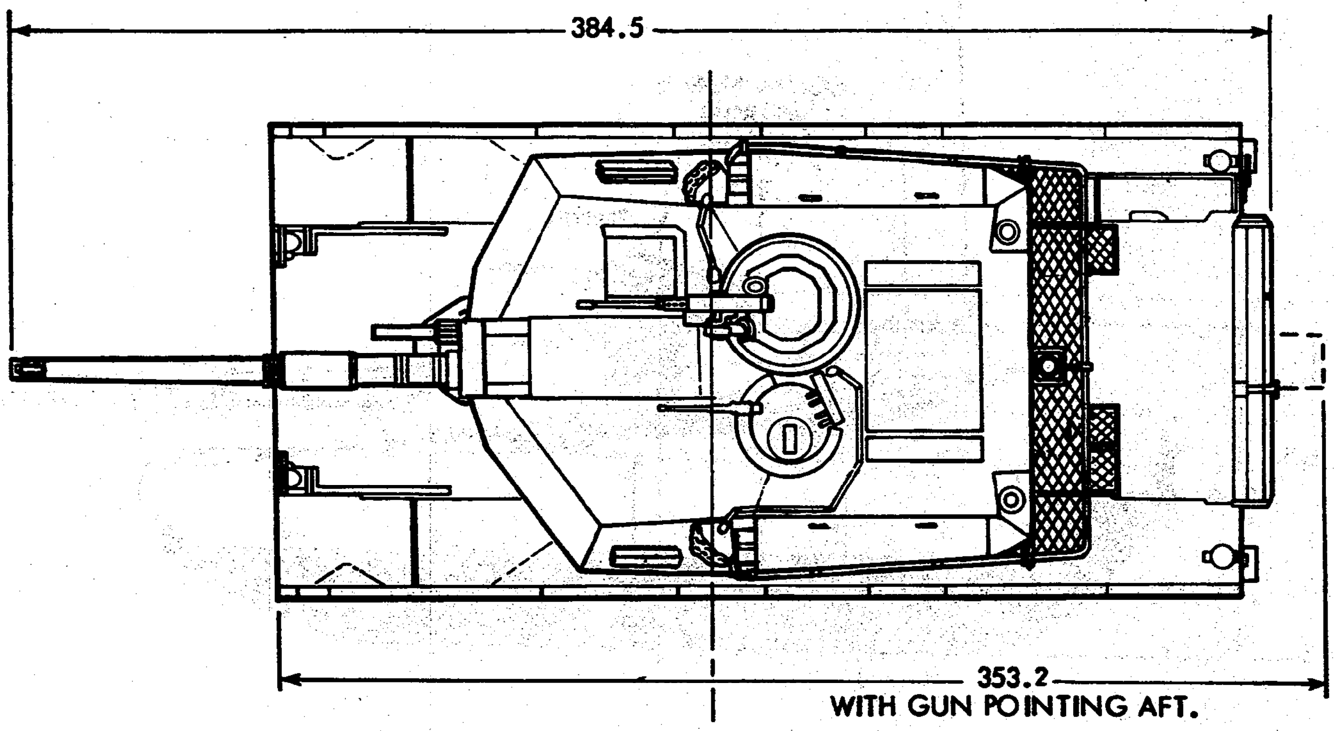


Figure 2-10. M1A1 Tank Dimensional Characteristics (Top View)

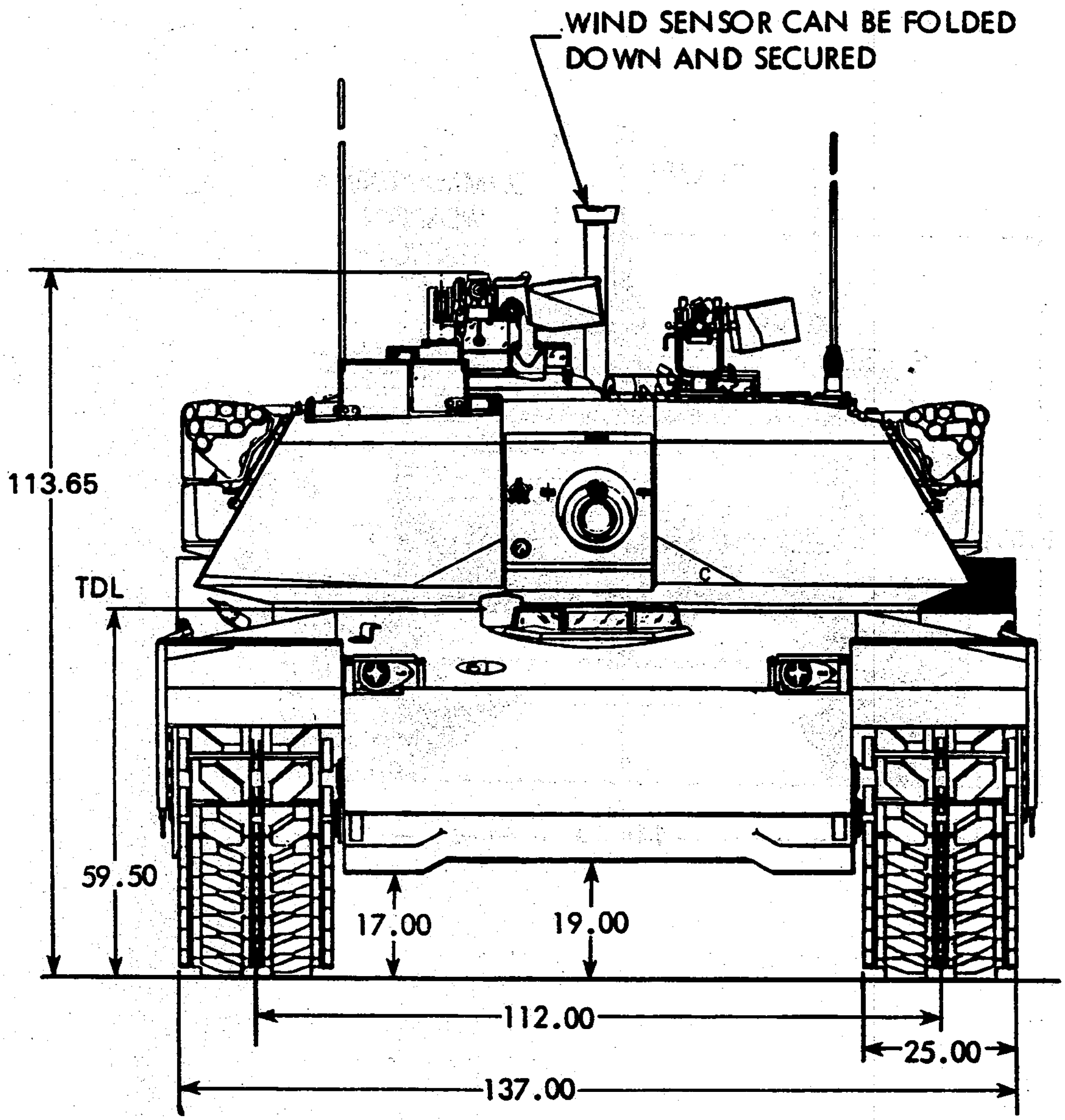


Figure 2-11. M1A1 Tank Dimensional Characteristics (Front View)

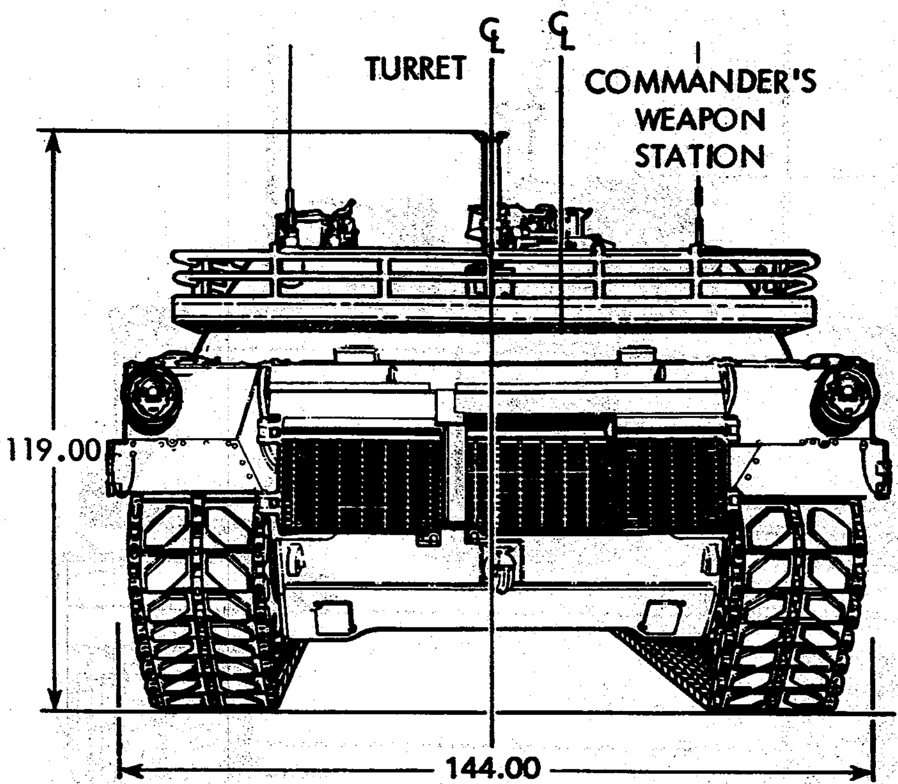


Figure 2-12. M1A1 Tank Dimensional Characteristics (Rear View)

Range (constant speed of 29 mph on dry and level paved roads, without refueling) - NBC on 279 miles
NBC off 289 miles

Fording Depth

- Without kit - 48 in.
- With kit - Turret Roof including bow wave

Braking

- Deceleration from speeds between 30 mph to maximum speeds on dry level paved roads - 13 ft/sec^2
- Deviation from straight line path (equal to or less than) - - - 6 ft in 50 ft

Obstacles

- Vertical step (forward direction) - - - - - - - - - - - - - - - - 42 in.
- Trench crossing (forward direction) - - - - - - - - - - - - - - 9 ft width

2.2.3 Armament

Main Gun	120mm, M256
Coax Machinegun	7.62mm, M240
Commander's Machinegun	.50 caliber, M2
Commander's Alternate Machinegun	7.62mm, M240
Loader's Machinegun	7.62mm, M240
Rifle	5.56mm, M16A1
Smoke Grenade Launcher	M250

2.2.4 Ammunition Stowage

Main Gun (120mm, XM256)	40 rounds
Coax Machinegun (7.62mm, M240)	10,000 rounds
Commander's Machinegun (.50 cal, M2)	1,000 rounds

Loader's Machinegun (7.62mm, M240)	1400 rounds
Crew Weapon (5.56mm, rifle)	210 rounds
Hand Grenades (M67)	8 grenades
Grenades (M250, smoke grenade launcher)	24 rounds

2.2.5 Fire Control and Surveillance

Gunner's Primary Sight (GPS)	
o Dual day optics (narrow field of view)	6.2^{o} at 9.5X
o Dual day optics (wide field of view)	16^{o} at 3X
o Close-in surveillance (unity field of view)	18^{o} at 1X
o Night vision optics (narrow field of view)	2.5^{o} by 5.0^{o} at 9.8X
o Night vision optics (wide field of view)	8.0^{o} by 15^{o} at 3X
o Sight stabilization	Elevation
o Laser rangefinder ranging capability	200 to 7,980 meters
Gunner's Auxiliary Sight	8^{o} at 8X
Emergency Firing Device	Standard M60A2-Type
Ballistics Computer	Digital Self-Checking
Gun/Turret Drive and Stabilization	Elevation and Azimuth
Commander's Primary Weapon Sight	Optical Extension of GPS
Commander's Weapon Sight	20^{o} at 3X
Commander's Day Vision Periscopes	6 per tank, 360^{o} at 1X
Loader's Day Vision Periscope	360^{o} at 1X
Driver's Day Vision Periscopes	3 per tank, 120^{o} at 1X
Driver's Night Vision Periscope (image intensifier)	35^{o} by 45^{o} at 1X

2.2.6 Suspension

Type	Hydro-Mechanical
Roadwheel Stations	7 per side
Torsion Bars	7 per side
Shock Absorbers (modular rotary)	3 per side
Track	Double Pin-Rubber Bushing with Integral Pad

2.2.7 Electrical System

Electrical Power (6 batteries, 12 volts)	24 vdc
Electrical Capacity (battery only)	300 amp hours
Alternator (charging system)	650 amp
Voltage Regulator	Solid State

2.2.8 Communications

Intercom	AN/VIC-1(V)
Radio Set	AN/VRC-12 or AN/VRC-64
Security System	T-SEC/KY-57 (2 units per vehicle)

2.2.9 Engine

Type (two spool gasifier/free-shaft power turbine with recuperator)	AGT-1500
Gross Horsepower	NBC on, 1463 hp at 3000 rpm NBC off, 1500 hp at 3000 rpm
Gross Torque	NBC on, 2561 lb ft at 3000 rpm NBC off, 2626 lb ft at 3000 rpm
Maximum Torque	NBC on, 3842 lb ft at 1500 rpm NBC off, 3885 lb ft at 1500 rpm
Engine Output Speed at Maximum Tank Speed (41.5 mph)	NBC on, 3150 rpm NBC off, 3150 rpm
Fuel Capacity (usable)	495 gallons
Oil Capacity (including oil cooler and lines)	6.25 gallons

2.2.10 Transmission

Type (hydrokinetic-fully automatic)	X1100-3B
Torque Converter (TC-897)	3 Element

Transmission Ranges	4 Forward and 2 Reverse
Steering (integral steer/throttle T-Bar control)	Hydrostatic
Turning Radius	Pivot to Infinitely Variable
Braking (two fully independent systems)	Hydraulic and Mechanical
Oil Capacity (including oil coolers and lines)	45 gallons

2.2.11 Final Drive

Type	Coaxial Planetary Gear Drive
Gear Reduction Ratio (final drive input to sprocket drive output	4.67 to 1

2.2.12 Turret

Main Gun/Coax Machinegun

o Elevation limit-forward (110 degrees right and left of tank centerline)	-10 deg to +20 deg
o Elevation limit-rearward (70 degrees right and left of tank centerline)	0 deg to +20 deg
o Traverse capability (in either direction)	360 deg
o Elevation tracking rate (powered)	0.25 mils/sec to 25 mils/sec
o Elevation tracking rate (manual)	10 mils/crank rev
o Traverse tracking rate (powered)	0.25 mils/sec to 75 mils/sec
o Traverse tracking rate (manual	5 or 10 mils/crank rev
o Elevation maximum slew rate (control handles)	400 mils/sec
o Elevation maximum slew rate (stabilization commands)	750 mils/sec
o Traverse maximum slew rate (control handles and stabilization commands)	750 mils/sec
o Traverse tracking rate (silent watch control)	up to 75 mils/sec
o Elevation tracking rate (silent watch control)	up to 25 mils/sec
o Slew rates for 1500 mil duration (silent watch control)	up to 300 mils/sec

2.2.13 Commander's Machinegun

Elevation limit	-10 deg to +65 deg
Traverse capability (in either direction)	360 deg
Traverse tracking rate (powered)	Variable up to 400 mils/sec
Traverse tracking rate (manual)	Variable up to 178 mils/sec
Elevation tracking rate (manual)	Variable up to 110 mils/sec

2.2.14 Loader's Machinegun

Elevation limits	-35 deg to +65 deg
Firepower coverage (loader's sector of responsibility to left of turret)	265 deg

2.2.15 Nuclear, Biological, and Chemical

Minimum Crew Compartment Pressurization (hatches closed)	
Normal	3.7 inches H_20
Gun Firing	0.0 inches H_20
Controllable Temperature	
High	80 ^oF
Low	65 ^oF
Minimum Ventilated Face Piece Air Supply	
Commander	3 standard ft^3/min.
Driver	3 standard ft^3/min.
Gunner	3 standard ft^3/min.
Loader-SCFM	3 standard ft^3/min.
Minimum Air Cooled Vest Air Supply	
Commander	14 standard ft^3/min.
Driver	14 standard ft^3/min.
Gunner	14 standard ft^3/min.
Loader	14 standard ft^3/min.

3.0 SYSTEM DESCRIPTION

This section contains functional and technical descriptions of the M1A1 Tank hardware elements. The tank hardware elements described herein are related to the following subsystems:

- Hull
- Powerpack
- Suspension
- Turret
- Fire Control
- Armament
- Auxiliary Automotive System
- Special Equipment and Kits

3.1 HULL

3.1.1 General Description and Function

The M1A1 Tank hull is compartmented into three basic areas consisting of the driver's station, the hull center compartment, and the engine compartment. The hull provides ballistics and environmental protection for the crew and internally stowed components. The hull also provides for proper interfacing with the suspension system, powerpack, turret assembly, on-equipment-materiel (OEM), NBC system, and contractor furnished kits as applicable. In addition the hull is designed for ammunition stowage, mounting of auxiliary automotive components and subsystems and NBC components. The hull assembly basic structural features are shown in figure 3-1.

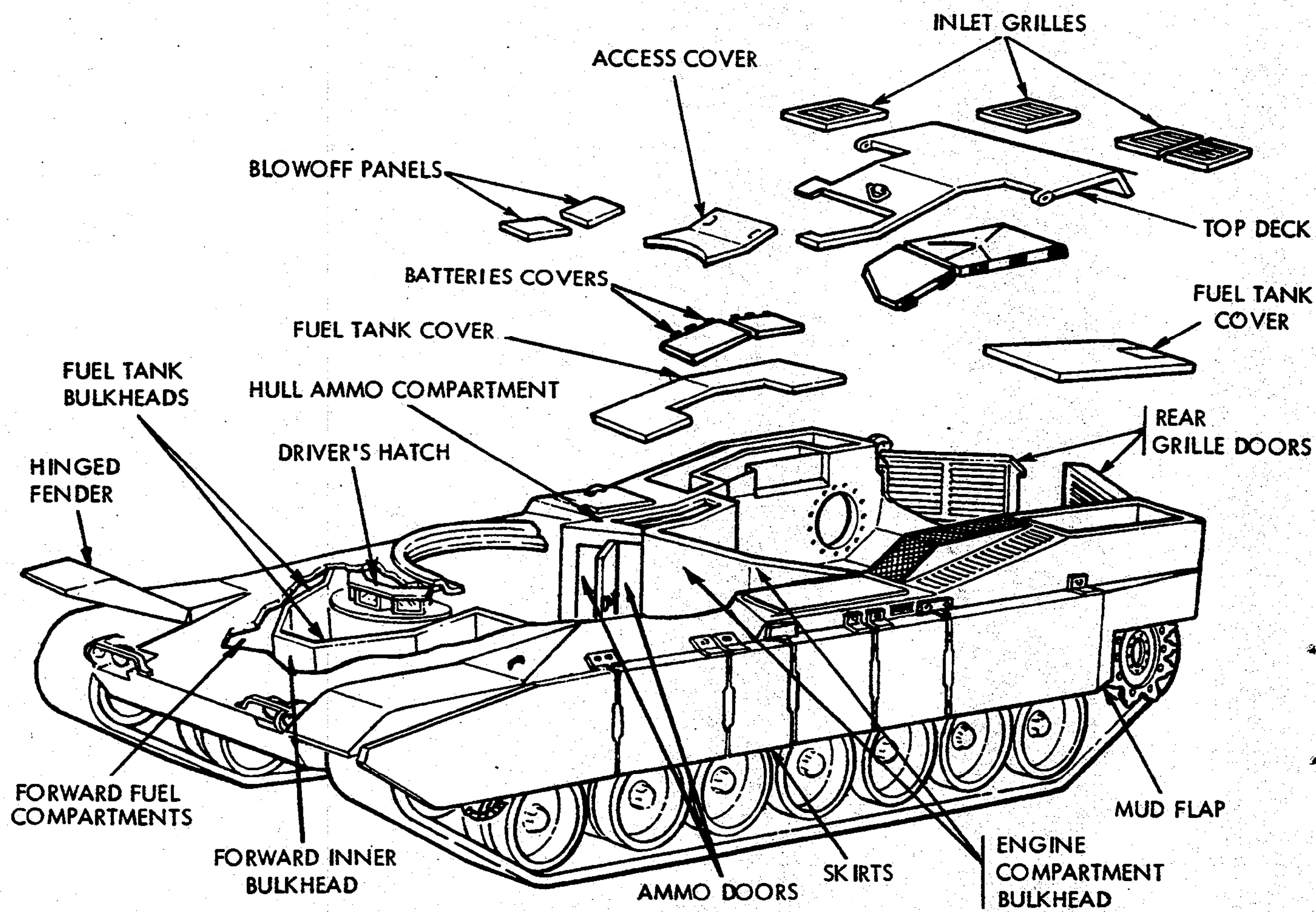


Figure 3-1. Hull Structural Features

3.1.2 Hull Structure

The hull structure is designed to ensure crew survivability and provide protection for internally mounted equipment against a broad spectrum of antitank weapons. The hull armor configuration consists of a weld-fabricated rolled homogeneous armor (RHA) structure with armor protecting the front and sides of the crew areas. Armor protection is also provided for the hull engine compartment and NBC components. Fuel and main weapon ammunition are separated from the crew in armored compartments. Fuel is isolated from the crew in three areas; the forward fuel compartments, the engine compartment, and aft in the sponsons. The hull ammunition compartment is an armored enclosure which is used for main gun round stowage. It is located aft of the engine compartment bulkhead on the right side of the tank and separated from the crew area by sliding armor doors. Two blowoff plates in the top deck and an open baffled area through the right sponson provide upward venting. Downward venting is through two blowoff plates in the hull bottom. The hull appendages, including the skirts, engine compartment top deck, air inlet grilles, rear grille doors, and the driver's hatch complete the hull protective envelope.

3.1.3 Hull Electrical

The hull electrical system consists of a power source, power control, and a distribution system. A two-wire, isolated return electrical system is incorporated and the power ground wire is routed with the corresponding hot wire in a twisted pair to maintain electromagnetic compatibility. EMI/EMP shielding on harnesses and electrical components has been used in accordance with M1A1 EMC/EMP design guidelines.

The vehicle power source consists of six lead acid batteries connected in a series/parallel configuration to provide a 24 vdc, 300 amp hour capacity. The battery system provides sufficient electrical capacity to meet the critical engine cold starting and silent watch requirements. The charging system uses a 650-amp oil-cooled alternator with a solid state regulator. These supply the vehicle electrical/electronic system power while maintaining fully charged batteries at approximately 60 percent of the alternator capability. All hull electrical system components, panels, and boxes are designed to operate with an input voltage of 18 to 30 vdc.

System reliability is maximized by using proven and established military specification components, low risk design practices, and high design safety factors. Electrical components such as relays, switches, wire, connectors, circuit breakers, and semi-conductors have been standardized to achieve consistently high performance.

System maintenance is facilitated with centralization of controls and interfaces and design features for fault isolation. A master warning light is located in view of the driver. It illuminates when a critical engine parameter malfunction or engine compartment fire occurs. Hull electrical control and power distribution circuit breakers are located on the power distribution box and networks box within easy access of the driver. Diagnostic test connectors are provided on all control panels and boxes for monitoring of interface signals to quickly isolate faults to the assembly level without removing components.

All harnesses, harness plugs, and panel receptacles are clearly marked for ease of identification. Numeric coding of individual wires simplifies tracing of circuits at higher levels of maintenance. This coding is reflected on all circuit schematics.

A utility outlet is provided on the hull networks box for operation of a trouble light, special power tools, or the OEM food warmer. The NATO slave receptacle is incorporated to provide standard slaving capability with the M1 series tank.

The vehicle is equipped with two vibration isolated headlights having high and low beam filaments and two front blackout markers. Two composite tail light/stop light units having rear blackout markers and blackout stop lights are also provided. In addition, IR filter lenses are provided for exchange with the headlight lenses to provide active IR illumination. When the IR filter lenses are in use the rear lights must be disconnected.

BATTERY CHARACTERISTICS

Type - Military type 6TN (lead acid)

Quantity - 6

Battery Connection - Series-parallel.

Capacity - 300 amp hours

Voltage Output	24 vdc
Weight	426 lb (71 lb each)

ALTERNATOR CHARACTERISTICS

Voltage	26 to 30 vdc
Output	650 amps - 28 volts at 2400 rpm
Cooling	Oil
Oil Flow	3 to 6 gallons/min
Weight	95 lbs
Special Provisions	Waterproof

REGULATOR CHARACTERISTICS

Type	Solid State
Voltage	28 vdc
Output	Field control
Weight	6 lbs
Special Provisions	Waterproof

3.1.4 Ammunition Stowage

Compartmentalization for main weapon ammunition is provided in the hull. Six main weapon rounds are stowed in the hull ammunition compartment shown in figure 3-2. This location is vented at the top and the bottom by blowout panels provided in the structure

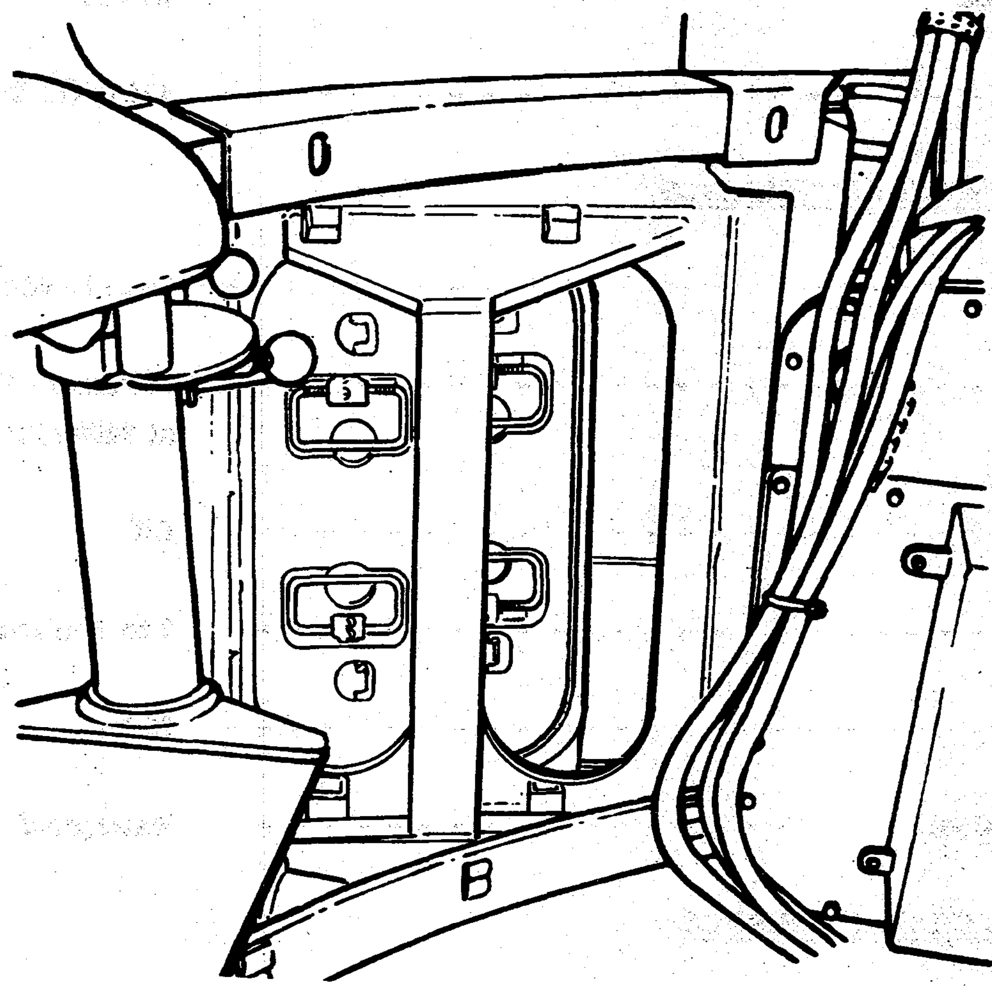


Figure 3-2. Hull Ammunition Stowage

of the hull. The hull main weapon rounds become accessible for transfer when the main weapon is over the left front fender. The hull-stowed ammunition is shielded from engine compartment heat and noise by a thermal and acoustical barrier on the compartment wall. Steel-covered layers of glass cloth on the engine compartment wall provide complete coverage. Plastic liners are located next to the round warhead, along the compartment wall, to absorb energy and protect the surrounding structure when ammunition is detonated.

3.1.5 Driver's Hatch

The hull includes a hatch positioned above the driver's station compartment which enables the driver to control the vehicle in a head-out position and functions as an escape hatch in an emergency situation. Three unity vision periscopes are mounted in the driver's hatch for closed-hatch driving. These periscopes provide the driver with an overlapping field-of-view exceeding 120 degrees forward vision.

3.1.6 Auxiliary Equipment

Provisions are provided within the hull for the vehicle hydraulic and electrical power distribution system including protection and control devices, batteries, and cabling. The hydraulic power distribution system includes the main pump, reservoir, hull manifold assembly, filter manifold, turret manifold assembly, auxiliary pump, ammunition door actuator, heat exchanger, and the pressure and return hoses and tubes. The hull also contains the vehicle fire extinguisher system. A NATO type slave electrical receptacle is provided, which, for security purposes, is accessible from inside the vehicle only and is connected to the vehicle prime power system. Provisions for towing are available at the front and rear of the vehicle, including a towing pintle mounted on the vehicle centerline at the rear of the hull.

3.1.7 Engine Compartment Deck, Grilles and Access Doors

The rear top deck of the hull over the engine compartment is a removable single unit structure to facilitate powerpack installation and removal. This panel which must be removed prior to detachment of the top deck, allows access to the engine accessories. Four hinged air-inlet grille doors are provided for the cooling system. Two hinged access doors are provided over the air cleaner.

3.1.8 Other Hull Access Doors and Covers

The hull structure also incorporates the following access doors and covers: bolted access covers over the sponson fuel compartments, hinged covers over the battery compartment, bolted access covers on the forward fuel tank bulkheads, two forward and two rear hinged ballistics protected fuel fill covers, an access door for the right sponson stowage box, NBC covers, a bolted access cover for the forward fuel tank cross-over pipe, sliding ammunition compartment doors, two bolted access plates for the final drive/transmission interface, a bolted inspection port for the engine air plenum seal, and a bolted cover for the hydraulic reservoir draining.

3.1.9 Skirts

The hull also includes skirts which in conjunction with the hull side armor provide protection against ballistics threats. The hull skirts open on vertical hinge lines to provide access to the suspension components.

3.2 POWERPACK

3.2.1 General Description and Function

The powerpack shown in figure 3-3 depicts the AGT-1500 turbine engine, the X1100-3B transmission, the final drive, the air cleaner system, the scavenging blower, and the cooling system. The powerpack and accessories are designed for ease of maintenance and can be removed quickly and easily. The powerpack weighs approximately 8,500 pounds and its dimensional characteristics are 119.0 inches (length), 80.0 inches (width), and 47.0 inches (height).

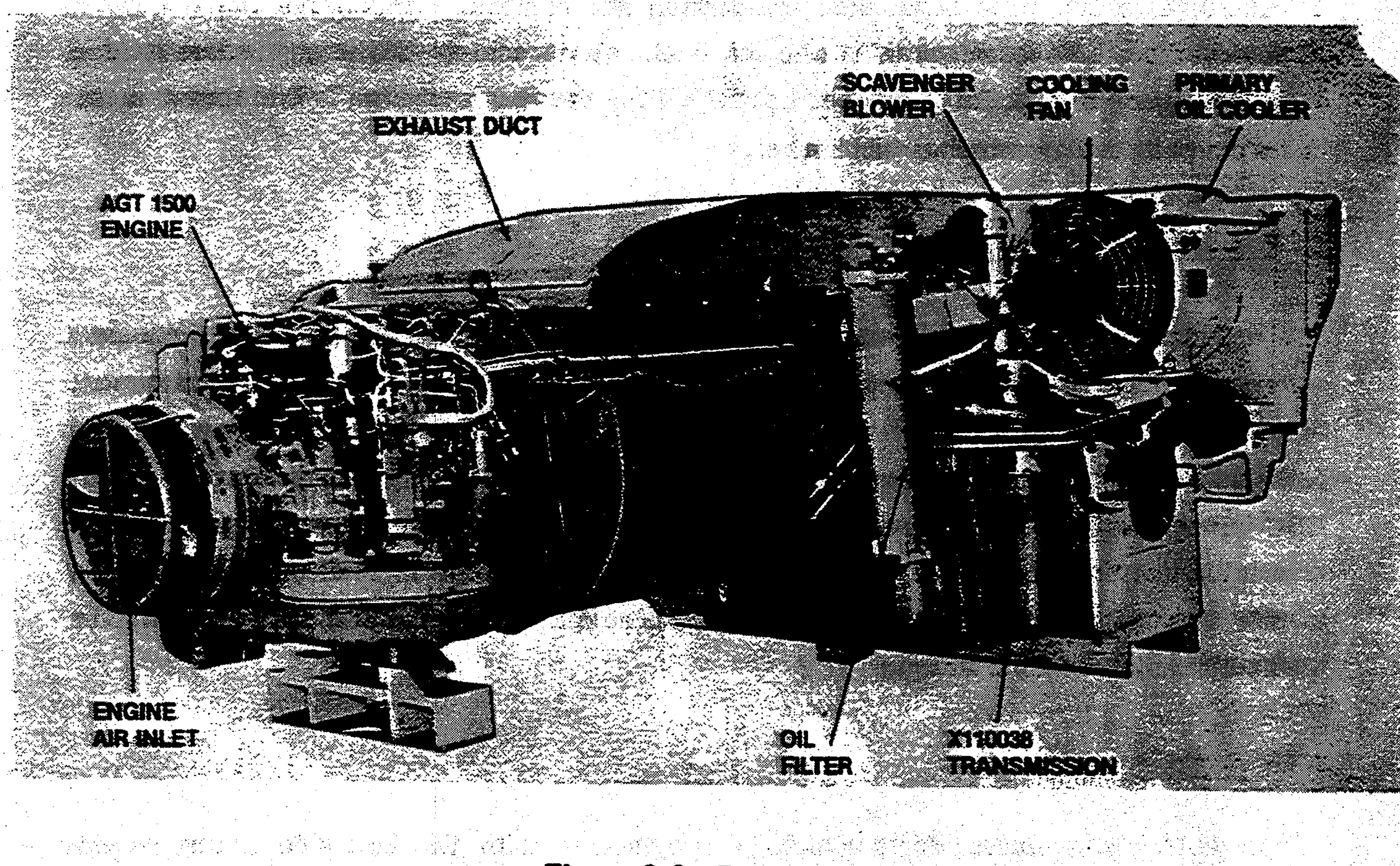


Figure 3-3. Powerpack

3.2.2 Engine

3.2.2.1 Description and Function

The M1A1 Tank turbine engine provides power to the transmission to drive the vehicle and the transmission mounted accessories. The AGT-1500 turbine engine shown in figure 3-4 is a free shaft power turbine engine with a two-spool gasifier and a cross-counterflow type stationary heat exchanger (recuperator). Basically, the engine consists of an air inlet and exhaust section, a five stage low pressure compressor, a five stage high pressure compressor, an accessory drive gearbox with starter, a combustor, a single stage high-pressure turbine, a single stage low pressure turbine, a two stage power turbine, a recuperator, and an output shaft and reduction gearbox. The engine also consists of a fuel management subsystem which includes an electrohydraulic metering device mounted on the engine and an electronic control unit mounted in the vehicle. The engine is equipped with a lubricating oil reservoir and has provisions for mounting and driving the vehicle hydraulic pump from the accessory gearbox. Integral electrical harnesses provide circuitry for engine controls and instrumentation.

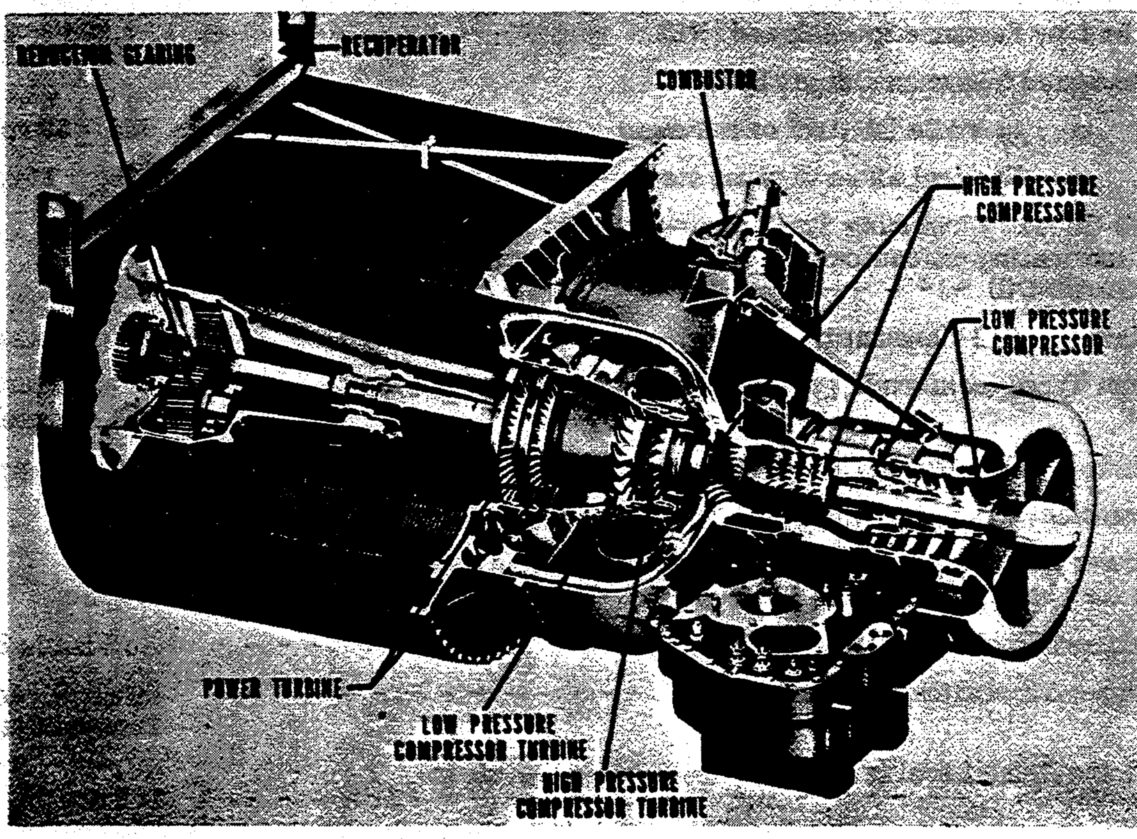


Figure 3-4. AGT-1500 Turbine Engine

3.2.2.2 <u>Engine Characteristics</u> (NBC Off)

Type	Two spool gasifier/ free shaft power turbine
Model	AGT-1500
Rated Shaft Horsepower at 3000 rpm Output Speed	1500 HP
Dimensions	
o Length	66.75 in.
o Width	39.0 in.
o Height	31.6 in.
Dry Weight (excluding starter and hydraulic pump)	2528 lbs.
Governed Maximum Output Speed	
o In Range	3,000-3,150 rpm
o Neutral and Pivot Steer	2,350-2,450 rpm
Maximum High Pressure Spool Speed (NH)	43,500 rpm
Maximum Low Pressure Spool Speed (NL)	33,000 rpm
Maximum Power Turbine Shaft Speed (at 3150 rpm Output)	23,000 rpm
Idle High Pressure Spool Speed (NH)	24,400 rpm
Idle Low Pressure Spool Speed (NL)	11,900 rpm
Governed Minimum Output Speed	
o Low idle (neutral or in range)	950 $\pm$ 50 rpm
o Tactical idle and pivot steer	1300 $\pm$ 100 rpm
Oil Capacity including 2 gal. cooler and line capacity (lubricating oil conforming to MIL-L-23699 and MIL-L-7808 Arctic Oil)	6.25 gal.
Maximum Oil Consumption	0.1 gallons per hour
Fuel Types (conforming to Federal specification VV-F-800)	DF-2, DF-1, and DF-A diesel fuel
Minimum Specific Fuel Consumption	0.475 lbs per hp-hr
Transient Response (from idle to 90 percent rated power)	4.0 sec
Power Decay Rate (from 100 percent rated to 20 percent rated power)	5.0 sec
Exhaust Smoke (normal conditions)	No Visible Smoke
Smoke Generation (camouflage)	Integral Part of Exhaust System
Engine Noise Level (at 50 feet and vehicle traveling 20 mph)	101 db

3.2.2.3 Air Induction System

The AGT-1500 engine air induction system uses a high efficiency air cleaner and an interconnecting duct providing filtered air to the engine. Figure 3-5 shows the air induction system arrangement. The air cleaner effectively filters incoming air in two stages. The first or primary stage inertial filters remove the bulk of the largest entrained contaminants via a vortex tube panel. The nonmetallic vortex tubes are treated with a fire retardant. The secondary stage filtration removes the remaining contaminants via barrier filters. These filters (i.e., V-packs) are fabricated of pleated paper treated with a fire retardant. Overall separation efficiency of the air cleaner is 99.8 percent when tested with SAE coarse test dust and 99.5 percent when tested with SAE fine test dust.

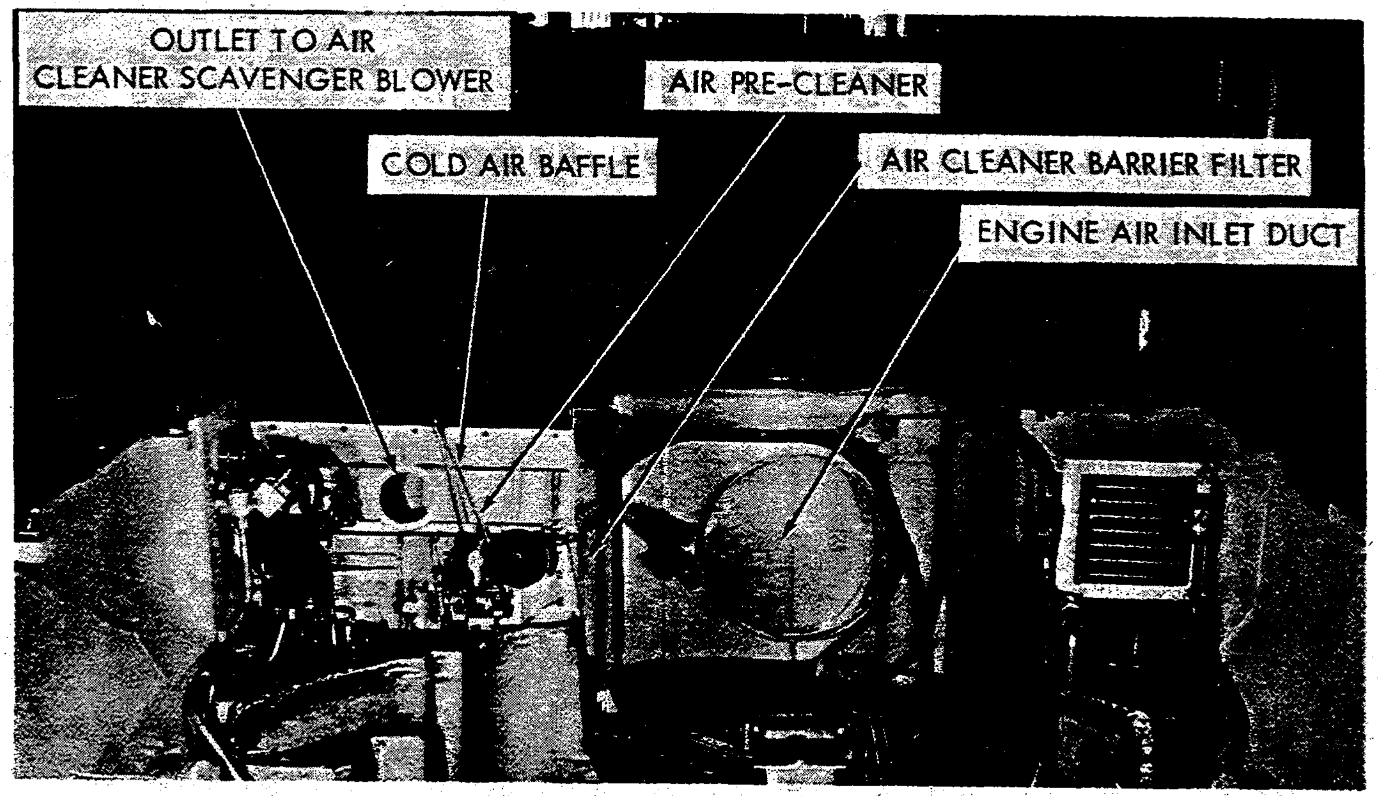


Figure 3-5. Air Induction System

The induction system is designed for 10,000 cfm of engine air flow with 1,000 cfm airflow for the scavenge exhaust system. The inlet grilles are sized for 11,000 cfm with minimum restriction.

The interconnecting duct is designed to provide flow into the engine bellmouth and to minimize flow loss.

The air cleaner service alert occurs at an air cleaner restriction of 25 inches of water (total system restriction equals 30.35 inches). Vehicle mobility is not impaired at this restriction level. The air cleaner is designed to sustain 20 hours of operation when ingesting coarse dust at a concentration of 0.025 gm/ft^3 before attaining a restriction of 25 inches of water.

The induction system is designed with the minimum number of connections to minimize leakage. The only connections between the filters and the engine are the V-pack barrier filter seals and the engine inlet seal, which is a circular dacron-reinforced rubber seal with a band clamp. A single air cleaner and mechanically driven scavenge exhaust blower minimizes complexity, space requirements, cost, and servicing. This blower is mechanically driven by means of a power takeoff shaft on the down stream side of the left cooling fan drive shaft. There are three V-pack barrier filters to service and no tools are required to remove or replace these elements. Baffles, which direct incoming cool air into the air cleaner, also eliminate contaminants and heated engine compartment air from entering the induction system. Sponson inlet grilles prevent shrapnel and small arms fire from entering the induction system.

3.2.2.4 Exhaust/Smoke Generating System

The engine exhaust system is designed to discharge exhaust gases with a minimum of recirculation into the engine compartment. The exhaust system consists of a double wall insulated duct from the engine to the rear of the vehicle. The inside and outside walls of the exhaust duct are fabricated from aluminized steel to prevent corrosion. A ceramic fiber insulation is used to prevent the outside of the duct from exceeding 300°F. Sixteen (16) bolts are used to attach the exhaust duct to the engine.

The exhaust system also incorporates a smoke generating system. Fuel is vaporized in the exhaust duct by spraying fuel into the rear section of the duct; the fuel will condense when exhausted to the ambient air and create the smoke cover. The smoke generator is designed to obtain maximum smoke emission with the use of minimum fuel flow. The smoke generating system is also designed to avoid fuel flow when the engine is not running to prevent the possibility of fires and prevent the fuel nozzles from becoming clogged.

3.2.2.5 Engine Control/Electrical System

The engine control system includes provisions for starting, overspeed and overtemperature protection, output speed governing (para. 3.2.2.2) for normal idle, tactical idle, maximum speed, and engine shutoff. The electronic fuel management system automatically provides the proper fuel flow for starting based on the engine temperature, thereby resulting in high starting reliability under all operational conditions.

To start the engine, the driver merely pushes the start button and within 60 seconds the engine achieves a stabilized idle condition and is immediately ready for vehicle moveout at full power. Engine control by the driver is attained by means of a power twist grip which increases fuel flow to the engine in accordance with load demand. With hands off operation, the minimum engine idle speed is maintained by the governor system at approximately 950 $\pm$ 50 rpm. This minimum idle speed will sustain a minimum vehicle speed of approximately 2.5 mph. The driver also has the option of increasing this minimum hands off governed speed to approximately 1300 $\pm$ 100 rpm during tactical operations for peak vehicle acceleration by engaging the tactical idle switch. The governor control system also limits the engine maximum output speed to approximately 3150 rpm which corresponds to a maximum vehicle speed of 41.5 mph. The governor has rapid response and will protect the engine against a sudden loss of load at full power. The driver has full control over the speed range between the minimum and maximum governed speeds.

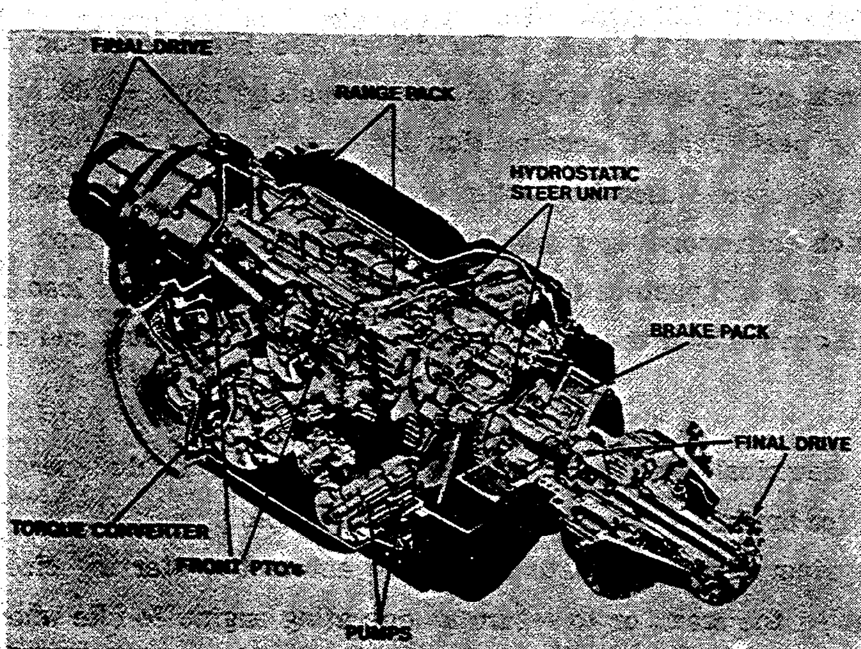
The engine electrical system is designed for highly reliable operation and ease of maintenance for both component replacement, and rapid powerpack removal, and installation. The system operation features include automated starting circuitry with safety lockouts to abort the start, or to return an operating engine to idle when critical failures are detected. Override start circuitry is available for emergency operation. Continuous monitoring is provided to the driver for critical operating parameters. Additional system features include an accessible starter motor, with adequate cranking power to provide reliable engine starting at cold temperatures, and a 650 amp alternator that uses engine oil for cooling and is mounted off the rear of the transmission. Other hardware includes the speedometer sensor, pressure, temperature and level switches, solenoid valves, and associated interconnecting wiring. The harnessing uses high temperature wiring and connectors with a viton polymer blend waterproof covering.

Electromagnetic Compatibility (EMC) and protection from Electromagnetic Interference (EMI) and Electromagnetic Pulse (EMP) compatibility are ensured by use of a two wire power system. All wiring is twisted shielded and uses RFI filters, where necessary, in accordance with the M1A1 EMI/EMP design guidelines.

3.2.3 Transmission

3.2.3.1 Description and Function

The X1100-3B hydrokinetic transmission shown in figure 3-6 is fully automatic and consists of a torque converter with an automatic lock-up clutch in combination with a four speed planetary range package. Hydrostatically controlled variable ratio differential steering is superimposed on the outputs through combining planetaries. Oil cooled brakes of multiple plate construction, integral to the transmission, provide vehicle braking. Oil filtration is provided by a dual filtration system.



The three element high capacity torque converter multiplies the characteristic high rise torque of the turbine engine and transmits it to the range pack. This combination of high converter capacity and high engine torque provides the desired acceleration, steering, and mobility characteristics. Under most operating conditions, a lock-up clutch is automatically engaged to bypass the converter and provide direct mechanical transmission of power. The ability to operate more efficiently in lock up under a greater percentage of conditions is a result of the high torque provided by the turbine engine.

The range package, consisting of five multiple disc clutch packs and three planetary gear sets, provides four forward and two reverse ranges (drive ratios) in a compact arrangement.

The drive ratios provided by the range package are sized to distribute engine power uniformly over the vehicle speed range, maintain engine operation in the most efficient speed range, and provide the sprocket torque needed for gradeability and tractive effort requirements.

Two front power takeoffs are provided for mounting and driving cooling fans, and a rear power takeoff is provided for mounting and driving (with integral right angle drive) the alternator.

A schematic of the major transmission components is shown in figure 3-7.

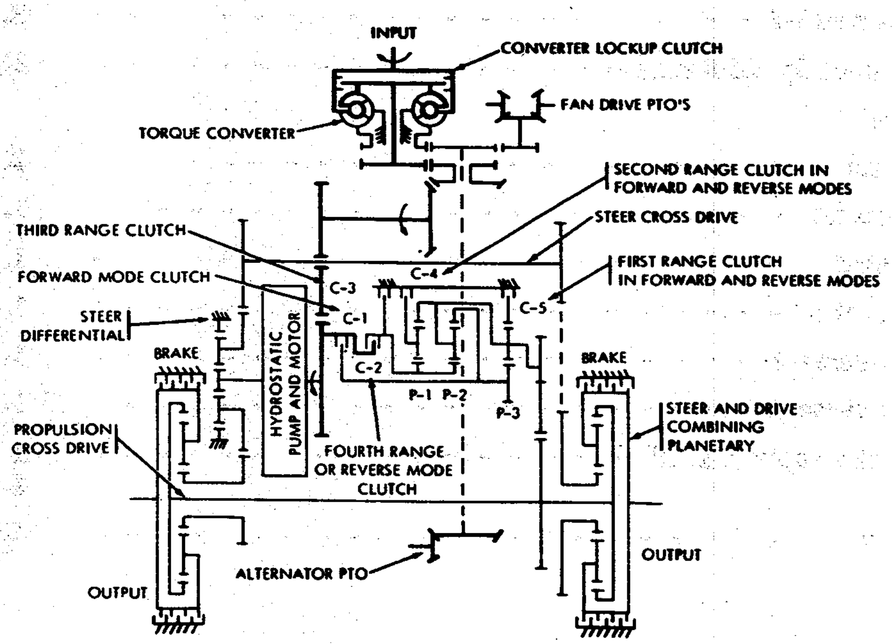


Figure 3-7. X1100-3B Transmission Schematic

3.2.3.2 Transmission Characteristics

Type	Hydrokinetic, Fully Automatic
Model	X1100-3B
Dimensions	
o Length	40.8 in.
o Width	62.0 in.
o Height	42.4 in.
Dry Weight (including oil filter and manifold)	4402 lbs
Maximum Gross Input Power (at 3000 rpm)	1500 hp
Maximum Net Input Power (at 3000 rpm)	1400 hp
Maximum Net Input Torque	3250 lb ft
Drive Ratios	
o First	5.88:1
o Second	3.02:1
o Third	1.90:1
o Fourth	1.28:1
o Reverse-1	8.30:1
o Reverse-2	2.35:1
Operating Input Speed Range	855 to 3200 rpm
Steer Ratios	
o First	2.34:1
o Second	1.52:1
o Third	1.30:1
o Fourth	1.19:1
o Reverse-1	3.51:1
o Reverse-2	1.38:1
Braking (brake apply shafts)	1 hydraulic and 2 mechanical
Oil Capacity	40 gallons

3.2.3.3 Controls/Modes

The transmission control system is designed to provide protection from overspeed caused by multiple downshifts, through provision of a backup signal from the lock-up governor, in the event of a shift governor signal failure. In addition, inhibited upshift points in both forward and reverse are set at a speed higher than the normal upshift but lower than the engine governed speed to ensure that a forced upshift occurs should the normal upshift not occur. Downshifts and forward/reverse shifts are also inhibited to preclude selection of an incorrect gear range.

Electrical signals are sent to the transmission from the driver's shift/range selector to provide the following ranges.

- Low (Automatic-First, Second, Third, and Fourth)
- Drive (Automatic-Second, Third, and Fourth)
- Neutral
- Reverse (Automatic-First and Second)
- Pivot Steer

3.2.3.4 Steering and Braking

The steer system includes a variable displacement radial hydrostatic pump coupled to a radial fixed displacement hydrostatic motor, a steer differential, and a regenerative steer cross shaft. This system produces equal and opposite variations in transmission output speed which provide the vehicle with the ability to maintain a given turning radius in a smooth predictable manner independent of soil conditions, provided vehicle speed is not sufficiently great to cause skidout. Pivot steering can easily be accomplished within 1.5 vehicle lengths. Maximum pivot steer rate is 7 rpm. To pivot, the driver must select the pivot steer position.

Vehicle braking is achieved through a multiple disc brake pack on each output shaft. Hydraulic pistons are used to actuate these discs. An entirely separate and independent parking brake apply system is provided through mechanical actuation of the discs with a ball/ramp cam. The brake system not only provides the capability to decelerate at 13 ft/sec^2, with little driver effort using the service brakes but also provides an independent hydro/mechanical backup in the event that the transmission hydraulic pressure is lost.

3.2.4 Final Drive

3.2.4.1 Description and Function

The final drive is a coaxial planetary gear drive speed reducer which transmits power from the transmission to the sprocket hub. The principal elements of the final drive are a bolting flange for mounting to the hull, a saddle and cap to support the transmission, an output shaft to mount and drive the sprocket hub, a disconnect input shaft, a vent, and an oil fill system.

3.2.4.2 Final Drive Characteristics

Type	Coaxial Planetary Gear Drive Speed Reducer
Gear Reduction (final drive input to sprocket drive output)	4.67 to 1.0
Input Power	750 hp at 2400 rpm
Static Input Torque (applied to input shaft)	30,000 lb ft
Static Radial Load	225,000 lbs
Free Spin Losses (input speed of 2400 rpm and no load on output shaft)	12 hp
Power Efficiency (output excluding free spin losses)	98 percent
Number Required Per Vehicle	2
Unit Weight	970 lb each
Oil Capacity (each)	5.5 quarts

3.2.5 Cooling System

3.2.5.1 Description and Function

The engine and transmission oil cooling is accomplished by the primary and auxiliary cooling systems shown in figure 3-8. The primary (engine and transmission) cooling system consists of a fan, fan drive system, cooling duct, transmission oil cooler, and engine oil cooler. A separate transmission auxiliary cooling system consists of a fan, fan drive system, cooling duct, and transmission auxiliary oil cooler. The systems maintain

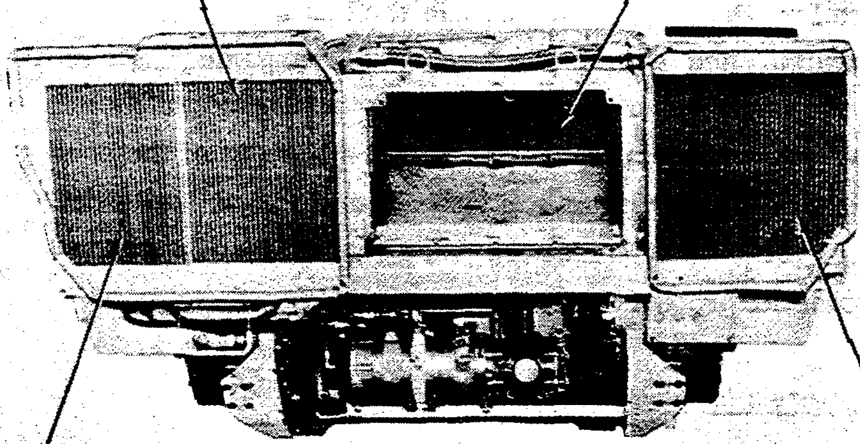


Figure 3-8. Cooling System

the oil temperatures within acceptable limits under extreme climatic and operating conditions. The cooling systems are designed to provide adequate cooling at a tractive effort of 0.67 times gross vehicle weight with NBC on and the ambient air temperature at 125°F. The fans for both systems operate at 1.732 times engine output speed, except that during deep water fording they are disengaged. The cooler cores are 6 inches thick and the fin spacing is varied to balance the airflow and maximize the system heat rejection. The engine cooler fin spacing is 18 fins per inch and the primary transmission cooler, which is mounted adjacent to the engine cooler of the primary cooling system, has a fin spacing of 15 fins per inch. The denser engine cooler core is located directly behind the fan to obtain a high cooler effectiveness which is required for engine oil cooling. The primary transmission cooler core airflow is partially obstructed by the transmission. The primary transmission cooler fin density and the transmission obstruction results in an airflow restriction equivalent to the engine cooler and therefore balances the airflow from the fan through both coolers. The transmission auxiliary cooler has 11 fins per inch and is smaller than the combined area of the engine and primary transmission oil coolers. The transmission auxiliary cooler fin spacing is opened up to reduce the static pressure drop through the cooler and optimize the system capability. The transmission auxiliary fan drive clutch is a spring loaded mechanical slip clutch that mounts inside the fan input housing. The clutch friction surfaces operate dry and directly engage an adapter connected to the fan blades. The bearings in the fan are sealed and are used to support the fan drive output and geared shaft. This arrangement allows the clutch to be incorporated in the fan drive without significantly increasing the distance between the fan and the fan drive shaft, thereby reducing the overall length of the cooling system. Gears and bearings for both fan drives are continuously cooled and lubricated with transmission oil. The cooling system inlet grilles are sized for 19,700 cfm with minimum restriction and maximum ballistics protection.

3.2.5.2 Cooling System Characteristics

Engine Oil Cooler

- Inlet oil temperature - 325°F
- Heat rejection - 4,300 BTU per min
- Oil pressure drop - 10 psi
- Air pressure drop - 4.3 in. of water
- Oil flow rate - 66.7 lbs per min
- Oil type - MIL-L-23699 or MIL-L-7808
- Airflow rate - 177 lbs per min
- Hydrostatic pressure - - - - - - - - - - - - - - - - - - - 400 psi
- Weight - 59 lbs

Transmission Primary Oil Cooler

- Inlet oil temperature - 300°F
- Inlet air temperature - 145°F
- Heat rejection - 6,252 BTU per min
- Oil pressure drop - 10 psi
- Air pressure drop - 3.3 in. of water
- Oil flow rate - 460 lbs per min
- Oil type - MIL-L-2104
- Airflow rate - 213 lbs per min
- Hydrostatic pressure - - - - - - - - - - - - - - - - - - - 600 psi
- Weight - 65 lbs

Transmission Auxiliary Oil Cooler

o Inlet oil temperature	275°F
o Inlet air temperature	145°F
o Heat rejection	7,500 BTU per min
o Oil pressure drop	15 psi
o Air pressure drop	4.95 in. of water
o Oil flow rate	460 lbs per min
o Oil type	MIL-L-2104
o Airflow rate	385 lbs per min
o Hydrostatic pressure	600 psi
o Weight	73 lbs

Cooling Fan

o Type	Dual or Single Stage Vane Axial
o Maximum input speed	5,300 rpm
o Design point fan speed	3,700 rpm
o Power required at design point	21 hp
o Fan airflow	7,500 cu ft per min
o Number required per vehicle	2
o Unit weight	90 lbs

Auxiliary Fan Drive Clutch

o Type	Mechanical
o Maximun input speed	5,300 rpm
o Minimum static torque	150 lb ft
o Weight	9.5 lbs

3.3 SUSPENSION

3.3.1 General Description and Function

The M1A1 Tank suspension system shown in figure 3-9 is a hydromechanical system which provides vehicle static and dynamic support through torsion bar springs and dampening of terrain induced vehicle oscillation by rotary hydraulic shock absorbers. Each side of the vehicle contains the following major sub-assemblies; compensating idler with track adjusting link, seven roadarm stations with dual roadwheels, two single wheel track support rollers, drive hub and dual sprockets, rotary shock absorbers, jounce stops at wheel stations 1, 2, and 7; and a 25 inch wide double-pinned rubber-bushed integral pad track.

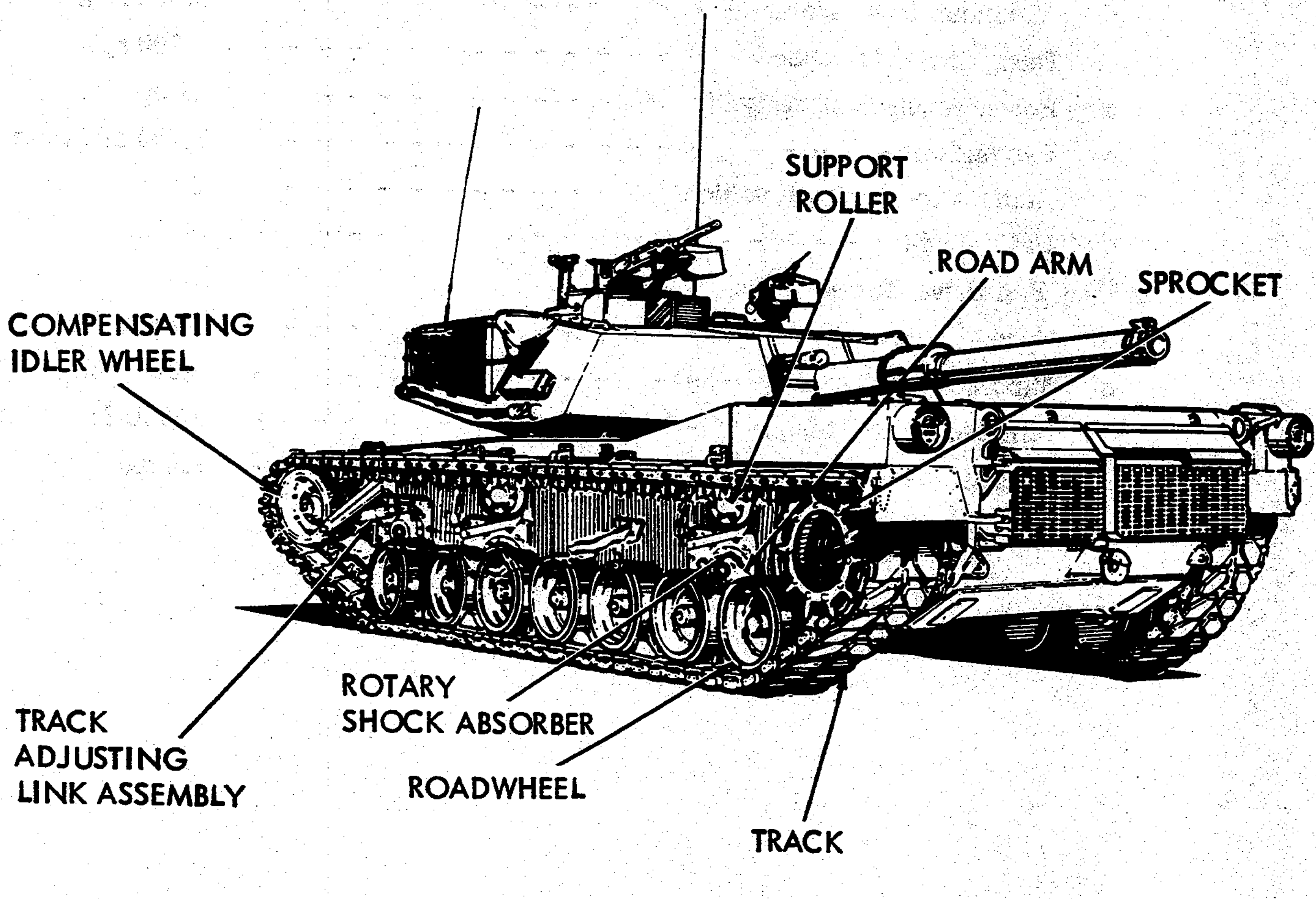


Figure 3-9. Suspension System

The compensating idlers and track adjusting linkages are located at the front of the tank and are connected to a roadarm on both sides of the vehicle. Track drive is accomplished through the track drive sprockets and hubs which are attached to the final drive assemblies at the rear of the tank. The track is supported and aligned between the drive sprocket and compensating idler wheel by two track support rollers.

Each road arm attaches to a housing assembly which is bolted to the hull. The weight of the vehicle, resting on the track and roadwheel, moves the road arm upward and produces a rotational movement in the upper spindle which causes a twisting of the torsion bars. As shifting vehicle weight moves each road arm upward, the twisting action of the torsion bars resist the motion and produces a springing action which supports the load and, at the same time, keeps the track in contact with the ground. Roadwheel positions are identified by numbers 1 through 7 starting with number 1 at the front of the tank and going to number 7 at the rear.

3.3.2 Suspension Characteristics

Type	Hydromechanical
Track	Integral Pad
Spring (seven per side)	Torsion Bar
Shock Absorber (three per side-stations 1, 2, and 7)	Rotary Hydraulic
Oil capacity per shock absorber	3 quarts
Roadwheels (seven stations per side, two wheels per station)	25 in. diameter
Roadwheel width (nominal)	5.99 in.
Ground Clearance (center portion of hull)	19 in.
Ground Clearance (other portions of hull)	17 in.
Cross-Country Speed (APG Terrain Profile IV)	All speeds up to 30 mph
Track Width	25 in.
Track Tension	10,000-15,000 lbs
Rolling Resistance	80-100 lbs per ton
Sprocket Pitch Diameter	26.8 in.
Length to Tread Ratio	1.61
Bounce Natural Frequency	1.16 Hertz
Pitch Natural Frequency	0.85 Hertz

Roadwheel Jounce Travel - - - - - - - - - - - - - - - - - -	15 in.
Composite Vertical Spring Rate - - - - - - - - - - - - - - - -	16,200 lbs per in.
Jounce Damping Force at Roadwheel - - - - - - - - - - - - -	6250-8100 lbs at 1 radian per sec velocity
Torsion Bar Spring Rate (each station) - - - - - - - - - - - -	460,000 in. lbs/radian
Suspension System Weight - - - - - - - - - - - - - - - - - -	22,223 lbs

3.3.3 Springs

The M1A1 Tank spring system consists of 14 high hardness steel torsion bars and covers with integral retainers that seal the covers. Figure 3-10 illustrates a typical assembly configuration for one spring. The aluminum tubular cover protects the torsion bar and spline areas from bilge contamination and because of the mechanical protection negates the need for the usual protective tape wrapping. The body is corrosion protected with a polyurethane varnish and the splines are covered with grease before installation. The spring system is designed to permit exterior access to the torsion bars from both sides of the tank. Thus, if a torsion bar breaks, each broken end of the bar can be pulled out. If there are any fragments, they will be contained in the aluminum cover tube from which they can be removed from outside the tank.

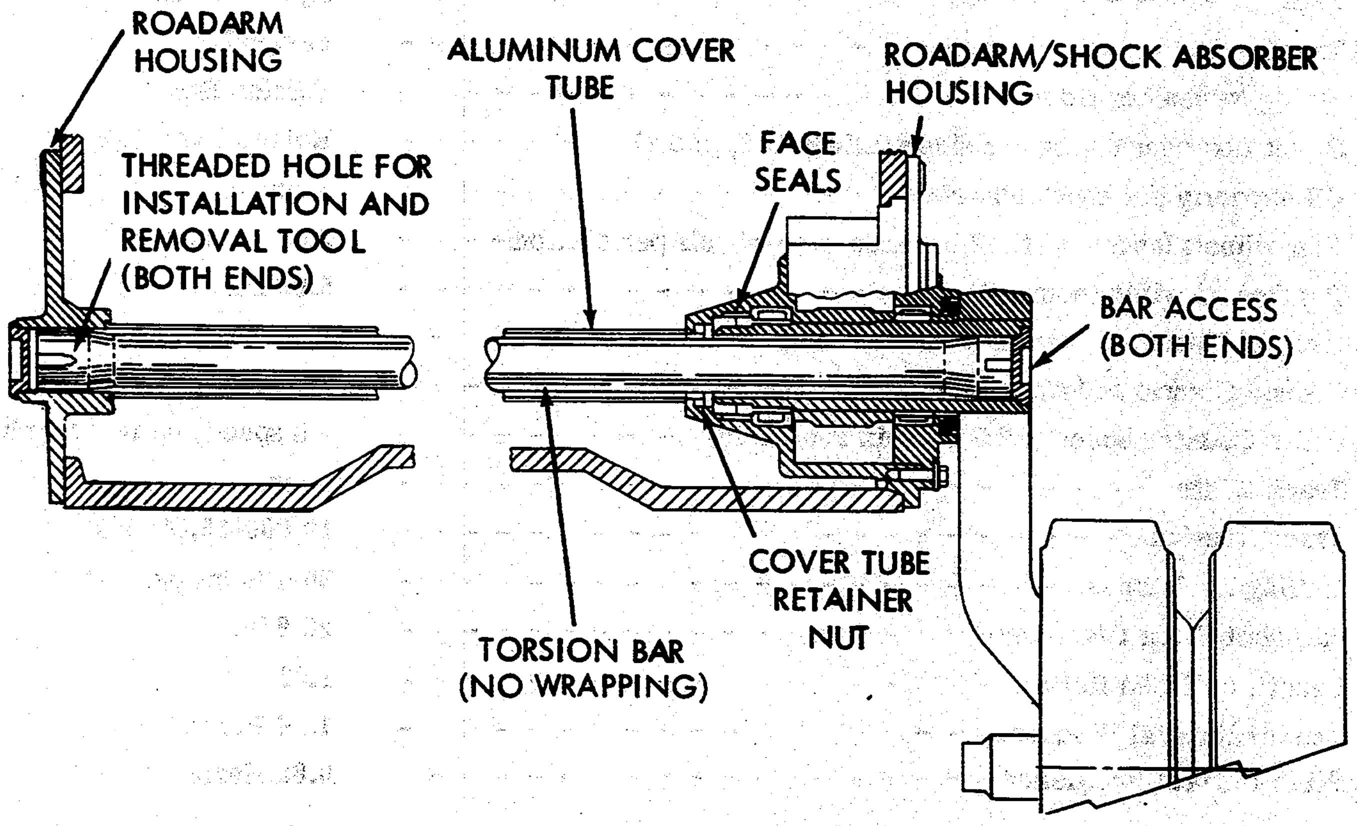


Figure 3-10. Typical Assembly Configuration - One Spring

3.3.4 Shock Absorbers

The modular rotary hydraulic shock absorber shown in figure 3-11 consists of two major elements: a rotor with two vanes that house damping valves and seals, and a stator with vanes and seals that complete the pressure chambers. The rotor is actuated by splines located on the upper roadarm spindle. The stator is held stationary by a key that reacts against the suspension housing. The shock absorber is assembled with four screws, and after installation it is held in place by the clamping force provided by the roadarm retainer. Installation and removal of the shock assembly requires no tools once it has been exposed by removal of the roadarm assemblies. Damping characteristics are controlled by four jounce valves and two rebound valves, all of which are relief type valves. The relief valves consist of cartridge assemblies that are set for proper cracking pressure before installation into the rotor. Each cartridge assembly is then threaded into the rotor vane, achieving cartridge sealing and locking in place by means of pipe threads. Shock absorber sealing is achieved by polyimide vane and end plate seals, all of which are actuated by the shock absorber oil pressure. Rotary hydraulic shock absorbers (a total of six) are used at roadwheel stations 1, 2, and 7 on both sides of the vehicle. Each shock

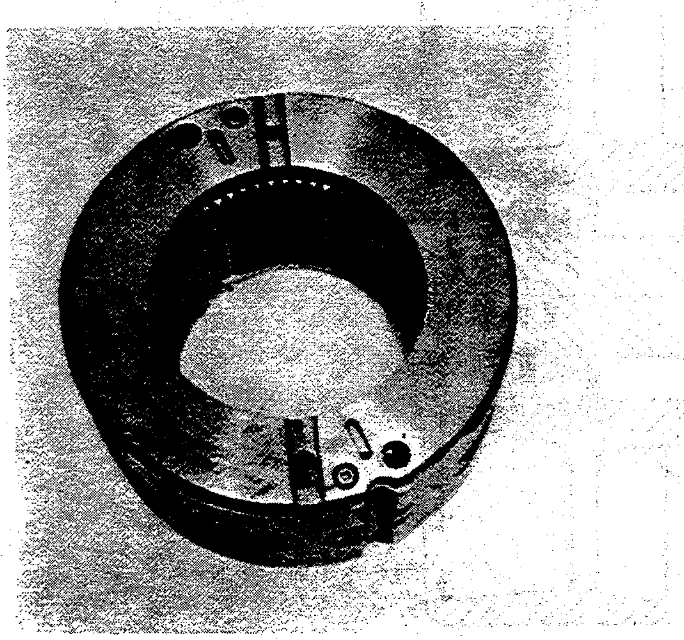


Figure 3-11. Modular Rotary Hydraulic Shock Absorber

assembly weighs 41 pounds and is supplied with oil from a reservoir which is an integral part of the suspension housing. MIL-L-46167 engine oil is used to achieve damping as well as to lubricate the bearings of the upper roadarm spindle assembly at the shock absorber stations. When oil is poured into the fill port located on the external face of the housing, it automatically floods the spindle bearings, fills the shock, and finally fills the reservoir. Each of the six shock absorber stations uses approximately three quarts of oil, of which 1.5 quarts are located in the reservoir. The design is such that overfill is impossible because the fill port establishes the maximum fill level. Monitoring of the oil level is done through an external sight gage.

3.3.5 Support Rollers, Roadarm and Roadwheel Assemblies

Two support rollers per vehicle side are used to support and guide the upper track segment. Each support roller consists of an 11 inch diameter single steel wheel which is integral with the wheel hub. The support roller housings are welded to the hull. The support roller assembly is shown in figure 3-12. Support rollers are grease lubricated and are sealed with lip type seals.

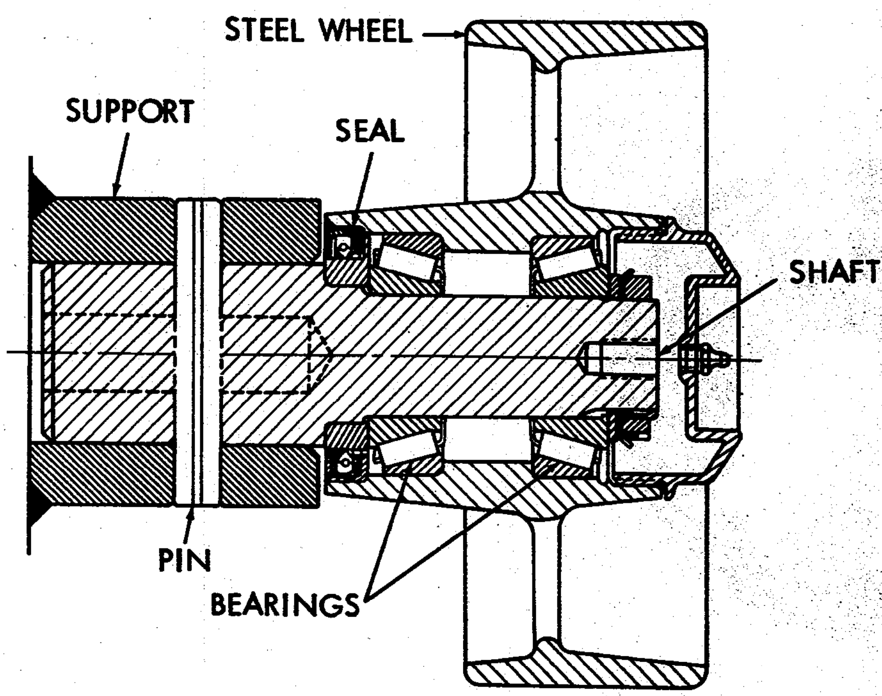


Figure 3-12. Single Wheel Support Roller

The suspension system includes 14 roadarm assemblies (seven roadwheel stations on each side of the vehicle) with built-in roadwheel camber. All roadarm assemblies contain two needle type bearings on the upper spindles that mount in the torsion bar support housings.

The housings at stations 1, 2, and 7 contain provisions for retention of the shock absorbers and have an integral reservoir for retaining the oil and supplying the oil to the shock absorbers. All housings are interchangeable right to left. The outboard seals at all roadarm upper spindle positions are metal face type to provide positive sealing and prevent outside contamination from entering the bearings. At the inboard upper spindle positions, face type seals are also used at stations 1, 2, and 7 to seal the shock absorber oil. The inboard seals at all other stations, which are grease lubricated, are elastomeric lip seals. None of the inboard seals are exposed to a dirt environment. The roadarm lower spindles which mount the roadwheel hub assemblies shown in figure 3-13 contain

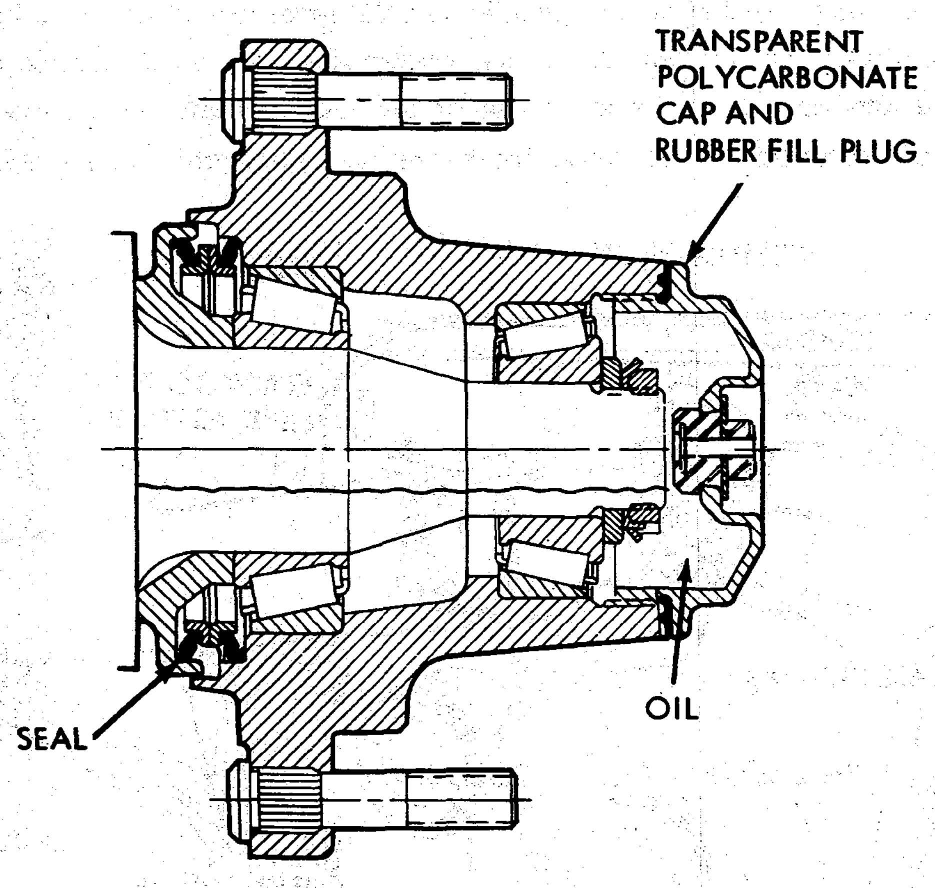


Figure 3-13. Roadwheel Hub Assembly

two tapered roller bearings and face-type seals and are lubricated with oil. The roadwheel hub assembly, which is used to mount the roadwheel at each station plus the idler wheels, includes the hub, seals, bearing adjustment components, screws, and the inboard and outboard bearings. Thirty two roadwheels are required per tank, 14 stations providing the ground support and two stations used as compensating idlers. The roadwheels are forged aluminum construction for minimum weight and contain integral bonded rubber tires. Steel wear plates with pressed in studs are attached to the roadwheels with washers and self-locking nuts. They provide the wear surface for contact with the track center guides.

3.3.6 Compensating Idlers/Track Adjusting Link

The compensating idlers consist of 25 inch diameter dual wheels, which are interchangeable with and identical to the roadwheels, and are attached to pivotally mounted idler arms. Track compensation under dynamic vehicle conditions is achieved by interconnection of the idler arms and the number one roadarms by the track tension adjusting link. Figure 3-14 illustrates the interconnection of the idler arm and number one roadarm with the track adjusting link. The static track tension adjustment is accomplished by hand

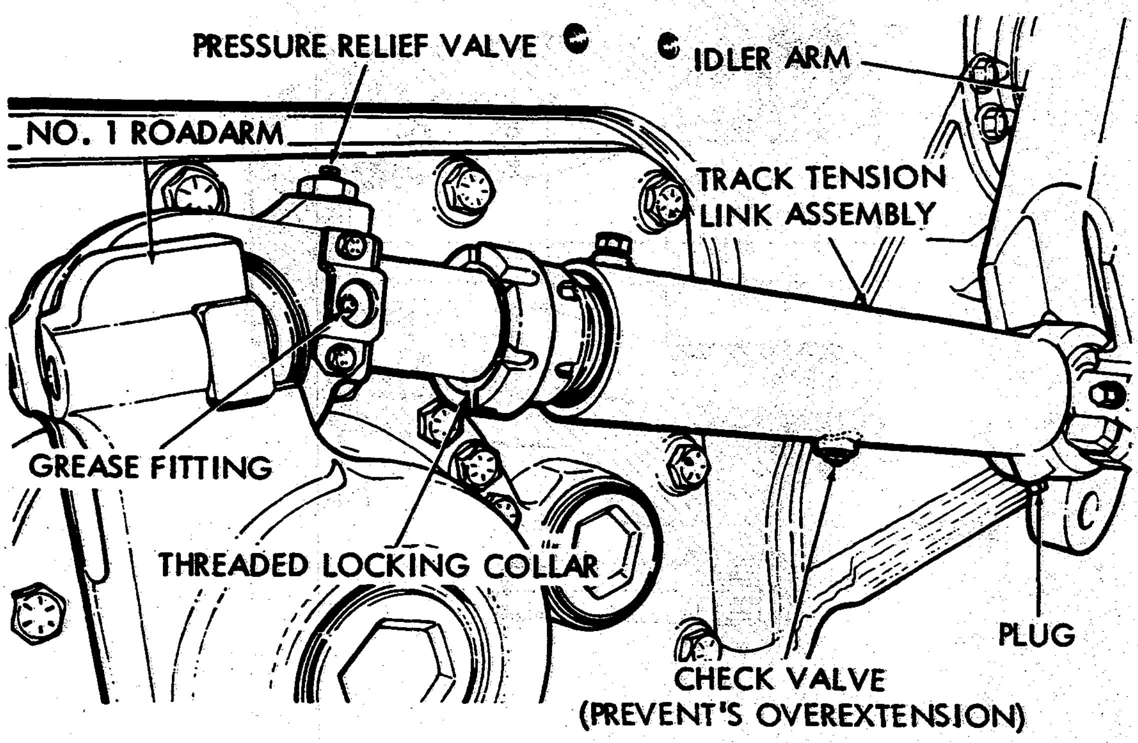


Figure 3-14. Track Adjusting Link

pumping grease into the link. A standard grease gun, which is part of the vehicle on equipment materiel (OEM), is used to accomplish this task. A pressure relief type valve is incorporated as part of the track adjusting link. This valve automatically opens when the proper pressure has been reached for correct track tension. The escaping grease will be plainly visible to indicate that proper tension has been achieved. After proper tension is achieved, the link is mechanically locked.

3.3.7 Hub and Sprocket Assembly

The hub and sprocket assembly shown in figure 3-15 consists of one steel hub and two sprockets. The hub contains large holes for dirt relief. The two steel sprockets are bolted to the hub to form the complete assembly. Two features of the tank hub and sprocket designs are notable: 1) the hub contains no guides for the track at the hub center, and 2) the sprocket bolt arrangement allow easy access for maintenance. Two hub and sprocket assemblies are required per tank and they interface with the final drive to transmit powerpack propulsion force to the tank tracks.

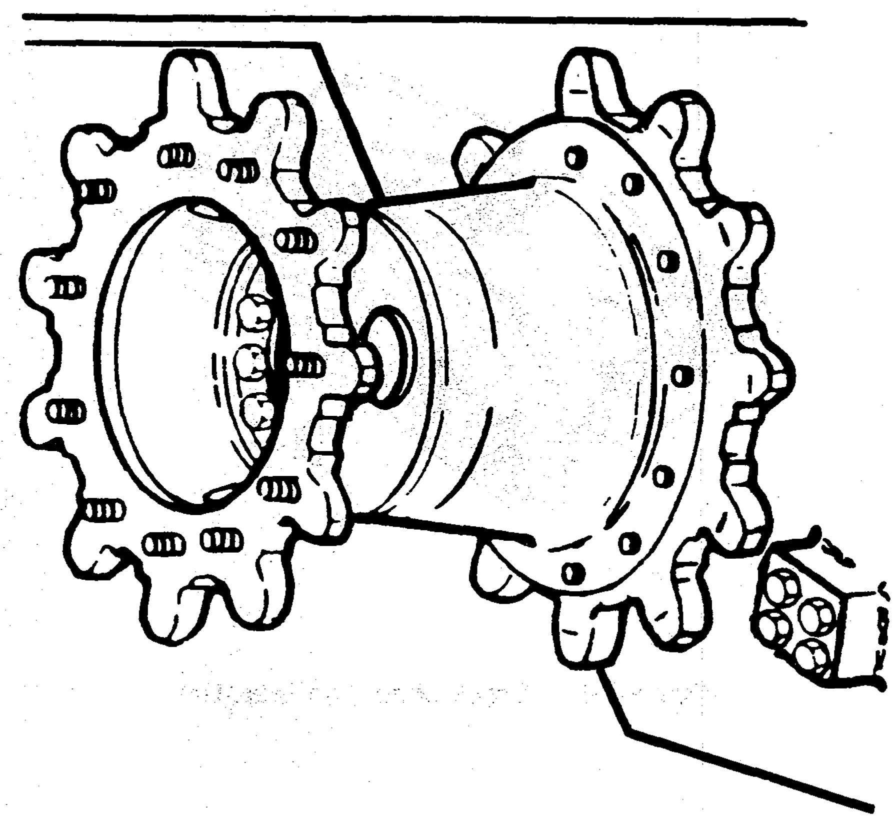


Figure 3-15. Track Drive Hub and Sprocket

The M1A1 Tank track configuration, depicted in figure 3-16, is an integral pad track with two rubber-bushed pins per shoe and integral rubber grousers. The track is 25 inches wide, with a pitch of 7.625 inches. Each track contains 78 shoes which result in a weight of 8,930 pounds per tank.

INTEGRAL PAD TRACK

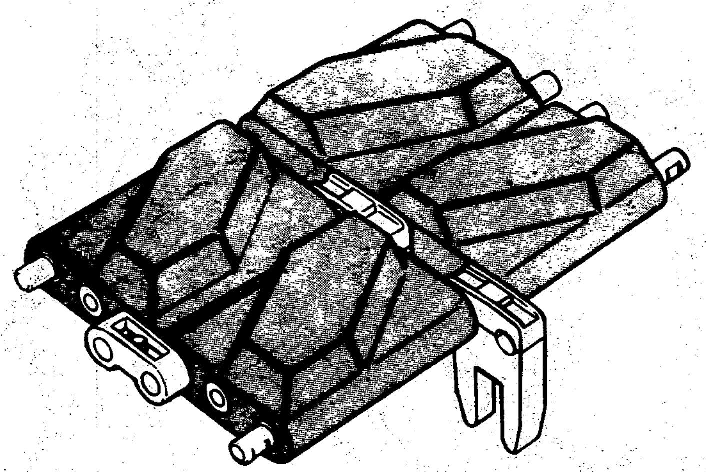
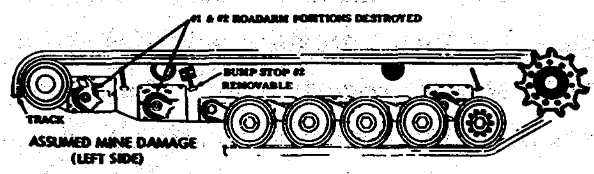


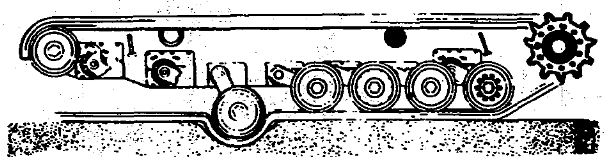
Figure 3-16. Track Shoe Configuration

3.3.8 Short-Tracking

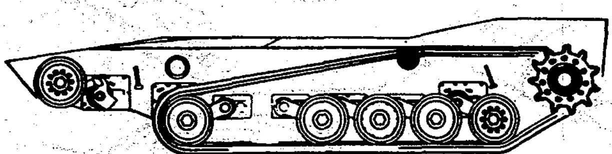
In the event of damage sustained from land mines, a short tracking feature shown in figure 3-17 provides the capability for operating the M1A1 Tank in a short-track mode. With damage to as many as two forward roadwheel stations the tank could continue to move by short-tracking. The basic steps for accomplishing short-tracking the tank are presented below.



1. REMOVE FIRST TWO SKIRT PANELS (NOT SHOWN)
2. REMOVE BUMP STOP NO. 2 BY TAKING OUT FOUR BOLTS
3. A. REMOVE DAMAGED COMPONENTS (WHEELS, HUBS, ETC) FROM NUMBER 1 ARM.
   B. DISENGAGE NUMBER 1 TORSION BAR AND MOVE ROADARM UP AGAINST BUMP STOP. RE-INSTALL TORSION BAR.
   C. REMOVE NUMBER 2 TORSION BAR AND ROADARM COMPLETELY.



4. REVERSE NO. 3 ROADARM
   A. REMOVE TORSION BAR.
   B. REVERSE ROADARM NO. 3 (MAKING IT A LEADING ARM) BY MOVING THE VEHICLE OVER A DEPRESSION IN THE GROUND (EITHER FROM MINE BLAST OR DUG BY HAND) AS SHOWN ABOVE.
   C. WITH ROADARM AT 45°, RE-INSTALL TORSION BAR.



5. WITH NO. 3 ROADARM IN LEADING POSITION WRAP TRACK AROUND ROADWHEELS AND NO. 2 SUPPORT ROLLER.
   NOTE: TRACK IS TO BE SHORTENED TO LENGTH REQUIRED TO FIT AS SHOWN.
6. USING TRACK JACKS CONNECT TRACK TOGETHER BY INSTALLING CENTER GUIDES AND END CONNECTORS.
7. SHORT TRACKING IS COMPLETE MOVE TANK AS REQUIRED.

Figure 3-17. Short Tracking

3.4 TURRET

3.4.1 General Description and Function

The M1A1 Tank turret is comprised of the following elements: turret structure, associated turret components, power distribution system, commander's weapon station, loader's station, gunner's station, ventilation system, mounts and feed system, fire control equipment, and main gun. The turret provides ballistics and environmental protection for the crew and internally stowed components. The turret also provides for proper interfacing with the tank hull, NBC components, stowage of on equipment materiel (OEM) and ammunition, accommodations for the crew (commander, gunner, and loader), and mounting of fire control components. The turret structural features are shown in figure 3-18.

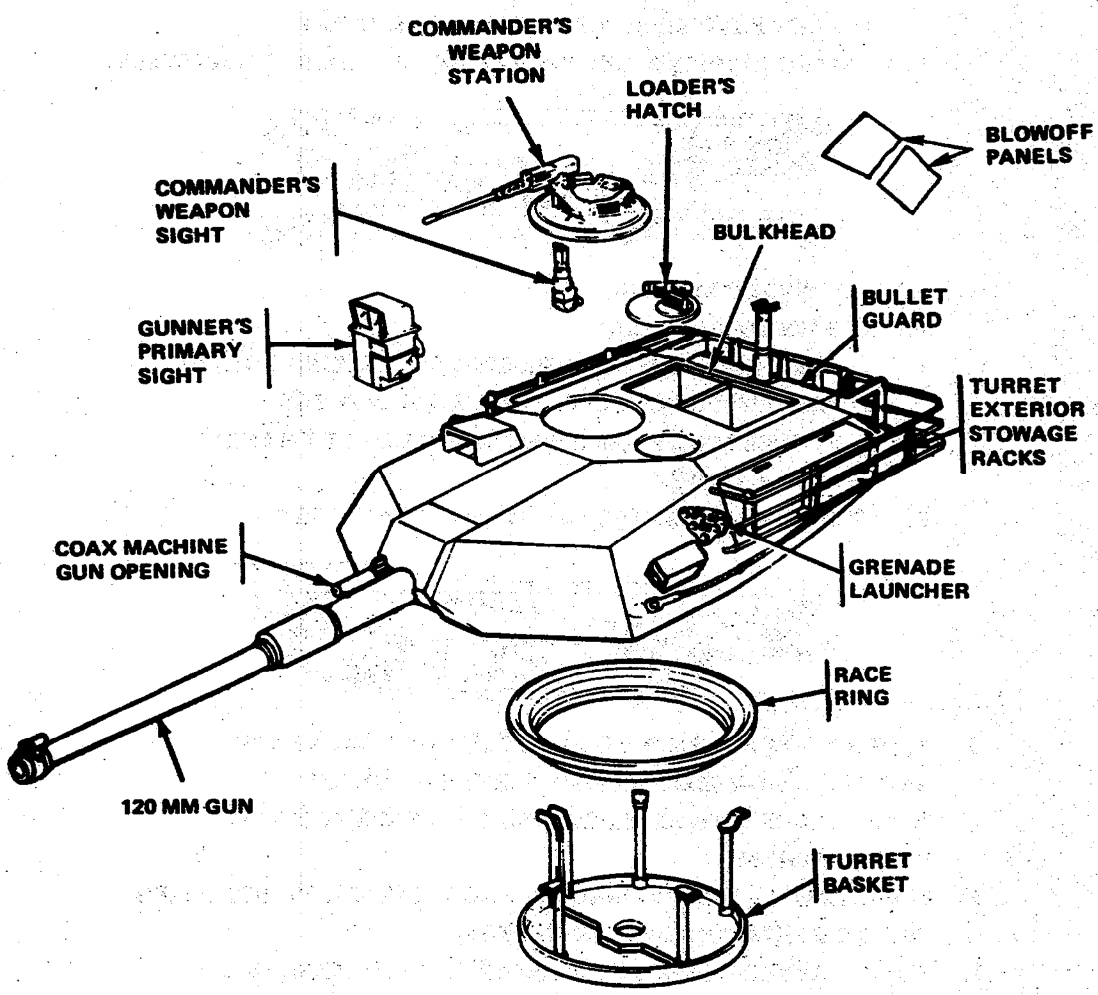


Figure 3-18. Turret Structural Features

The turret structure is designed to ensure crew survivability and provide protection for internally mounted equipment against a broad spectrum of antitank weapons. The turret armor configuration consists of a weld-fabricated rolled homogeneous armor (RHA) structure which protects the front and side of the crew areas and the turret bustle. The turret crew area comprises that part of the turret forward of the bustle ammunition doors and above the turret basket. The turret bustle ammunition compartment provides for main gun round stowage and occupies the portion of the turret aft of the bustle ammunition compartment doors. Bustle ammunition compartment venting is done upwards by means of blowoff plates and rearward through open venting (actually closed by sheet metal covers to block dust and water). The commander's and loader's hatch, main gun rotor, and armor gun shield complete the turret protective envelope.

3.4.2 Turret Basket

The turret basket shown in figure 3-19 is a circular aluminum armor plate with a rim and harness guide functioning as stiffeners. The floor hangs from five posts, four of which serve dual functions: the commander's seat mounts off one post, the loader's seat mounts off another, the electric and hydraulic lines are mounted through the third, and the hydraulic accumulator is mounted to a fourth. For convenience and safety, screen type guards are installed to protect crew members. A door in the basket floor provides access to various components mounted on the hull floor such as the hull gyro, governor, hydraulic components, and electrical lines. The basket structure is designed to provide spall protection with minimum weight and maximum stiffness. Stops are mounted in the hull to prevent excessive deflections and stresses from large dynamic loads, such as those resulting from a ballistics impact or a collision.

3.4.3 Turret Electrical

The turret electrical system emphasizes ease of operation, ease of maintenance, proven reliability, and significant growth potential. It features many design improvements over other tank systems. System operation has been greatly simplified by a thorough integration and standardization of panels and controls.

A vehicle master power switch, in parallel with another at the driver's station, is provided in the turret for added convenience and safety. The gunner and commander are provided with a separate, independently adjustable, control for varying indicator lamp intensities. The commander, gunner, and loader each have a separate adjustable dome lamp to control light levels for convenience and security.

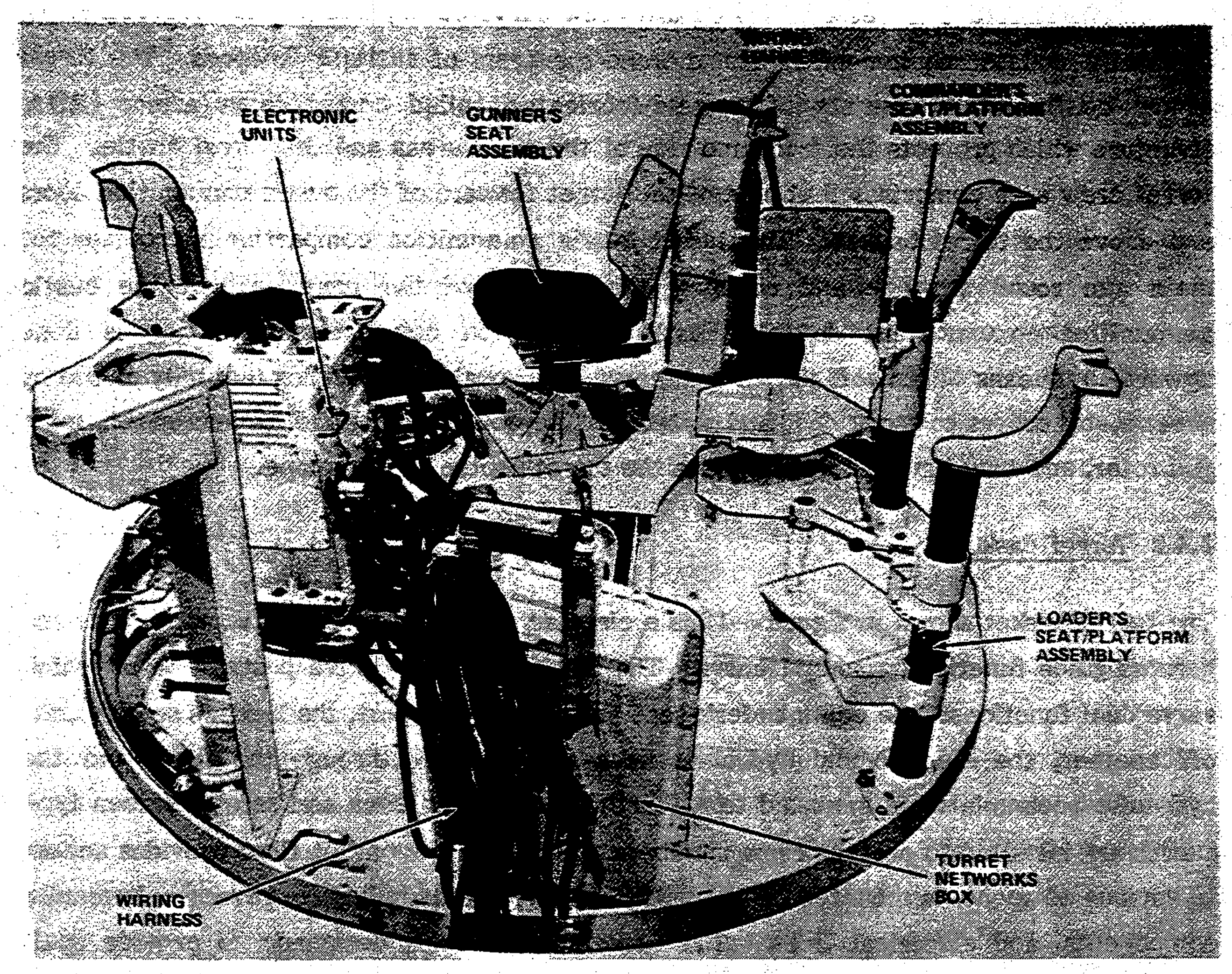


Figure 3-19. Turret Basket Assembly

Maintenance of the system is facilitated by many design features which enhance the ability to fault isolate and repair the system. Control, interface, and power distribution circuitry, as well as all the turret circuit breakers, have been centralized into one Turret Networks Box (TNB) located at the loader's station. This integration greatly reduces the time and effort required to return a system to operation. Diagnostic test connectors are provided on the TNB for monitoring of interface signals to isolate faults to the black box level. A utility outlet is also provided on the TNB for powering a trouble light, food heater, etc. Warning indicators for open circuit breakers, low battery charge, engine fire, and the NBC system are also provided at the commander's station for immediate recognition of possible problems. Indicator lamp test controls are also provided so that failed indicator lamps can be identified and replaced by the crew with no loss of time. All harnesses, harness plugs, and panel receptacles are clearly marked for easy identification. Alphanumeric coding of individual wires simplifies tracking of circuits at higher echelons of maintenance. This coding is reflected on all circuit schematics.

System reliability is maximized by utilizing proven military specification components with established reliability, by utilizing low risk designs, and by utilizing high design safety factors. Most electrical components such as relays, switches, connectors, wire, semiconductors, and circuit breakers have been standardized to achieve ease of maintenance.

System growth potential is addressed by providing a minimum of ten percent spare pins in all major electrical connectors, by allocating space inside panels and boxes for extra components, and by operating the system at approximately 60-percent power capacity.

Major design improvements include the hull/turret slipring which provides filtered air, hydraulic power, and electrical power between the hull and turret. A drum-type slipring has been selected over a larger platter-type on the basis of cost, producibility, reliability, maintainability, and performance characteristics. EMI, RFI, EMP, and electrical compatibility effects have been minimized by extensive use of RFI shielding on harnesses and electrical components, by utilizing a two-wire power distribution system, and by maintaining a separate turret-power bus for fire control and other sensitive circuits.

3.4.4 Hydraulic Power Supply and Distribution

The main hydraulic system shown in figure 3-20 provides up to 50 horsepower for the operating demands of the gun/turret drive system and the turret ammunition door actuation system. Hydraulic power is also provided to the crew compartment bilge pump and the hydraulic assist park brake system. The total capacity of the hydraulic system is 19 gallons, which includes the 18 gallons in the reservoir and 1 gallon in the lines. A variable-displacement,pressure-compensated pump is interfaced directly to the turbine engine accessory drive unit. This 1,600 psig pump is electrically depressurized during the engine starting cycle. Hydraulic power redundancy is provided with a one-horsepower electric auxiliary pump, to provide power for the gun/turret drive system during engine off and emergency operations.

The turret ammunition-door actuation system employs a linear actuator that is hydraulically decelerated at each end of the door travel. The controls include a solenoid operated directional valve that is actuated by the loader's knee switch.A pressure compensated flow control valve limits and controls the actuating speed of the door. A cross pilot-operated check valve is used to hydraulically lock the actuator and door.

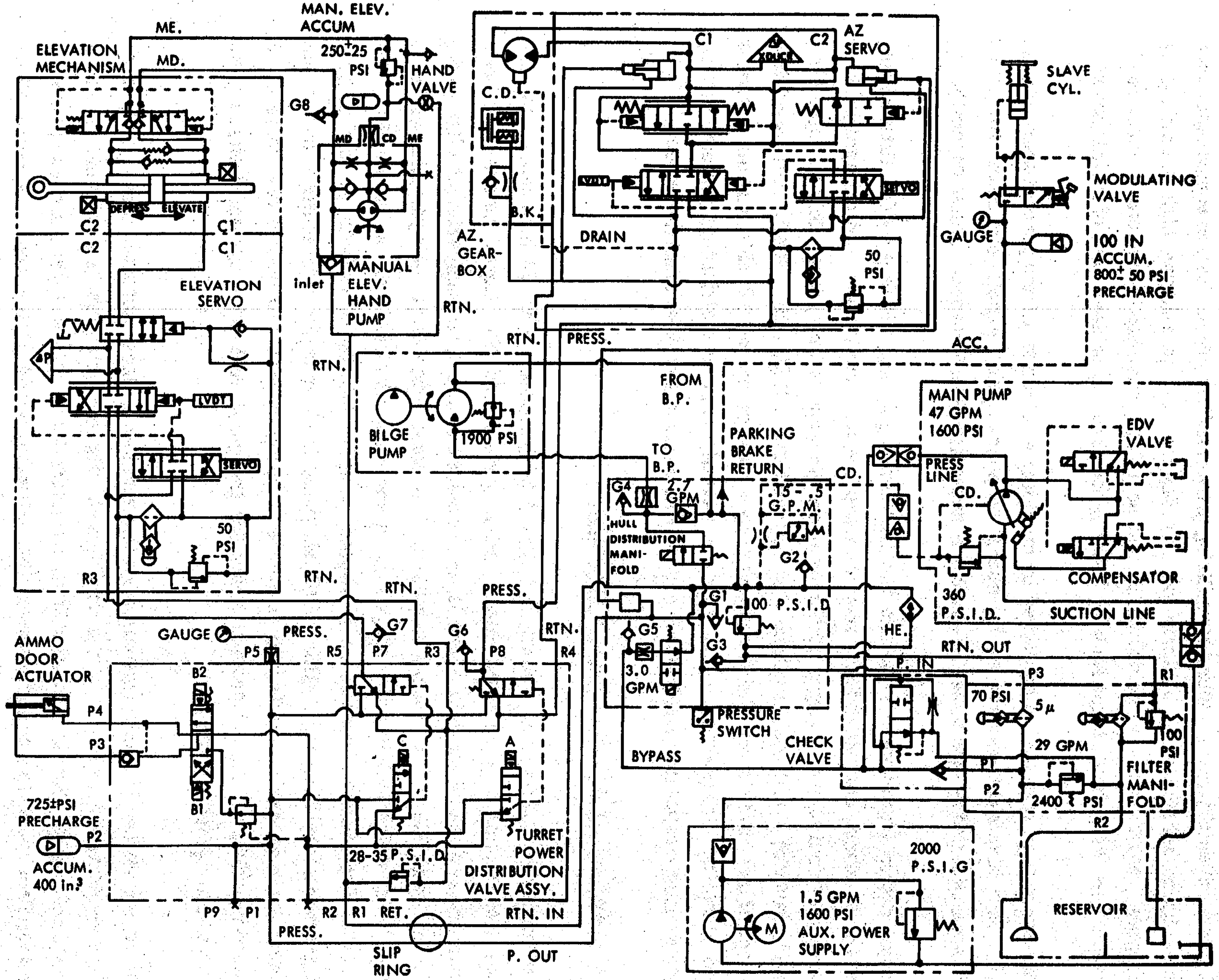


Figure 3-20. Hydraulic Power Supply and Distribution

An accumulator, precharged with nitrogen, supplements the hydraulic flow in excess of the system output for main gun deck clearance during rapid turret traversing.

A filter manifold and reservoir located in the hull are fully integrated with vehicle layout and are readily accessible for ease of maintenance. Filter elements require service only when self-contained differential pressure indicators pop out to visually alert the crew of a maintenance requirement. Self-sealing quick disconnects are used for easy uncoupling of hydraulic lines for component servicing or engine removal. Tubing for the system is stainless steel, MIL-T-8808 (a high performance tubing). Stainless steel ferrules are brazed on tubes and flareless type fittings conforming to military specifications are employed to provide for reliable, leak-tight, hydraulic connections. Swaged fittings are used in hard to reach, non serviceable areas.

Thermal stability of the system is maintained with the use of a simple finned-tube crossflow heat exchanger which is integrated with the vehicle cooling system.

Added crew survivability is provided with the use of MIL-H-46170, fire resistant, synthetic hydrocarbon, hydraulic oil and by isolating the hydraulic reservoir from the crew with an armored shield.

The main and auxiliary hydraulic systems provide the Gun/Turret Drive (G/TD) and control systems with adequate power for all mission and emergency operations. The selection and arrangement of components and incorporation of crew survivability features provide high vehicle mission reliability and ease of maintenance.

Hydraulic distribution complexity and potential leak points have been reduced by providing hull and turret valve and manifold assemblies. The hull manifold includes: the bilge pump control valve, the bilge pump flow/speed control, the auxiliary system pressure control switch, the main pump case drain flow sensor, the main pump cooling bypass, and the heat exchanger bypass.

The turret manifold contains the ammo door solenoid control valves, ammo door pressure regulation, the azimuth power valve, and the elevation power (uncouple) valve pressure gage.

3.4.5 Turret Accommodations

3.4.5.1 Ammunition Stowage

The primary objective for main weapon ammunition stowage compartmentalization shown in figure 3-21, is to improve crew survivability. The turret bustle provides the most logical location due to ease of venting hot gases, ease of sealing the area from the crew, and accessibility of stowed ammunition to the loader. There are 40 rounds of 120mm ammunition stowed in the M1A1 Tank, all of which are compartmentalized, either in the hull or turret bustle. The compartmented turret bustle stows 34 rounds, 17 of which are ready rounds directly accessible to the seated loader behind a knee switch actuated compartment door. The other 17 bustle rounds are also easily accessible but require that the loader leave his seat. The remaining 6 rounds are stowed in the hull compartment.

The bustle stowed rounds are shielded from engine and engine exhaust heat by a thermal insulation barrier attached to the outside of the engine exhaust duct. Additional thermal protection from the powerpack is provided by the deck and grilles and the air space between the hull and turret bustle. Plastic liners are located next to the round warhead, along the compartment wall, to absorb energy and protect the surrounding structure when ammunition is detonated.

The stowage of 7.62mm and .50 caliber machinegun ammunition is based on consideration for accessibility, quantity, interchangeability, and vulnerability. The quantity of complementary weapon ammunition stowed in the M1A1 Tank is tabulated as follows:

Ammunition	Quantity (Rounds)
7.62mm (total)	11,400
7.62mm (coax ready)	2,800
7.62mm (loader ready)	200
.50 cal. (total)	1,000
.50 cal. (ready)	100

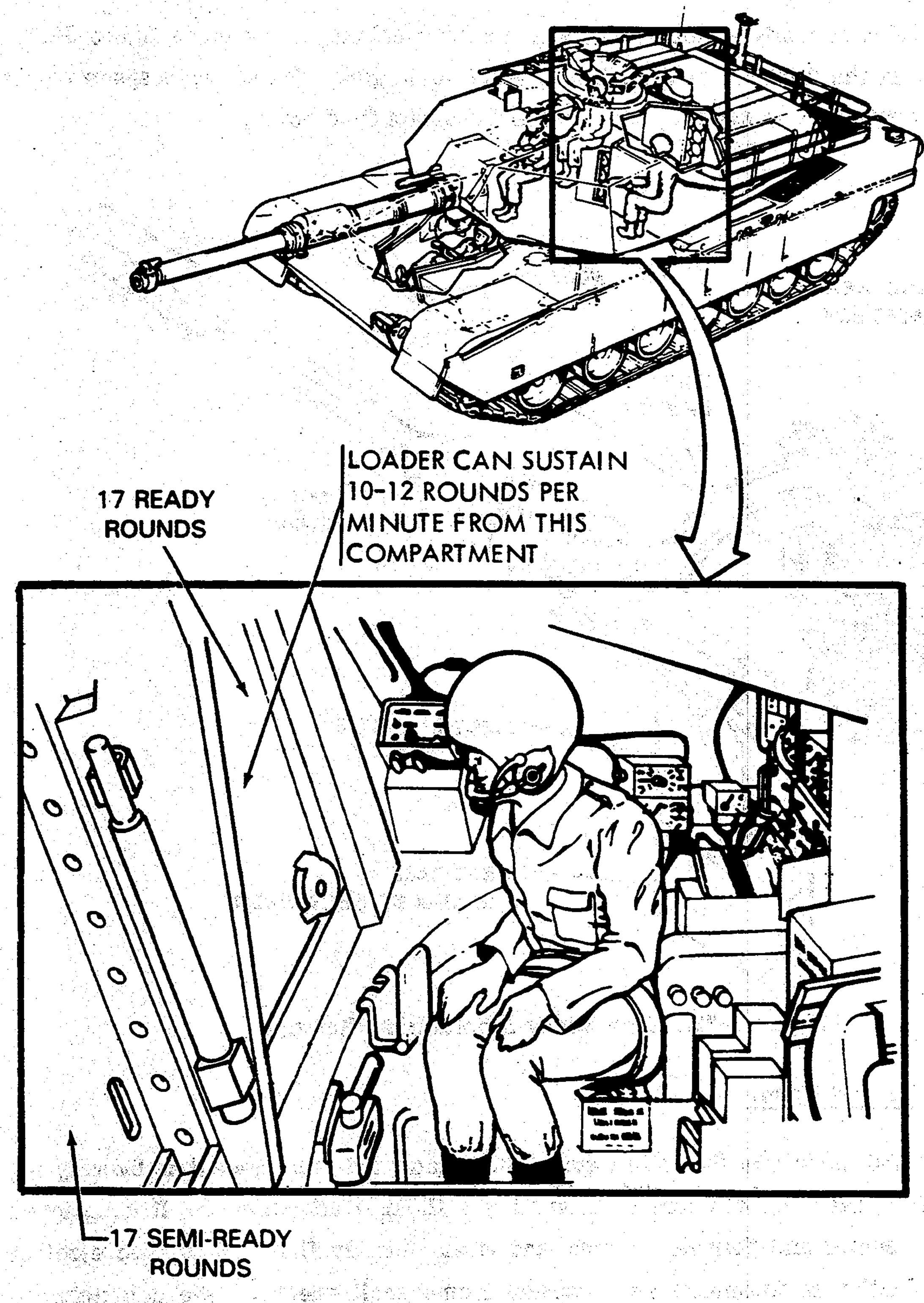


Figure 3-21. Main Gun Ammunition Stowage

Stowage of 7.62mm ready ammunition for the coax machinegun shown in figure 3-22, is concentrated on the left side of the 120mm, M256 main gun. The stowage space outside the turret is configured to accept .50 caliber and 7.62mm field boxes.

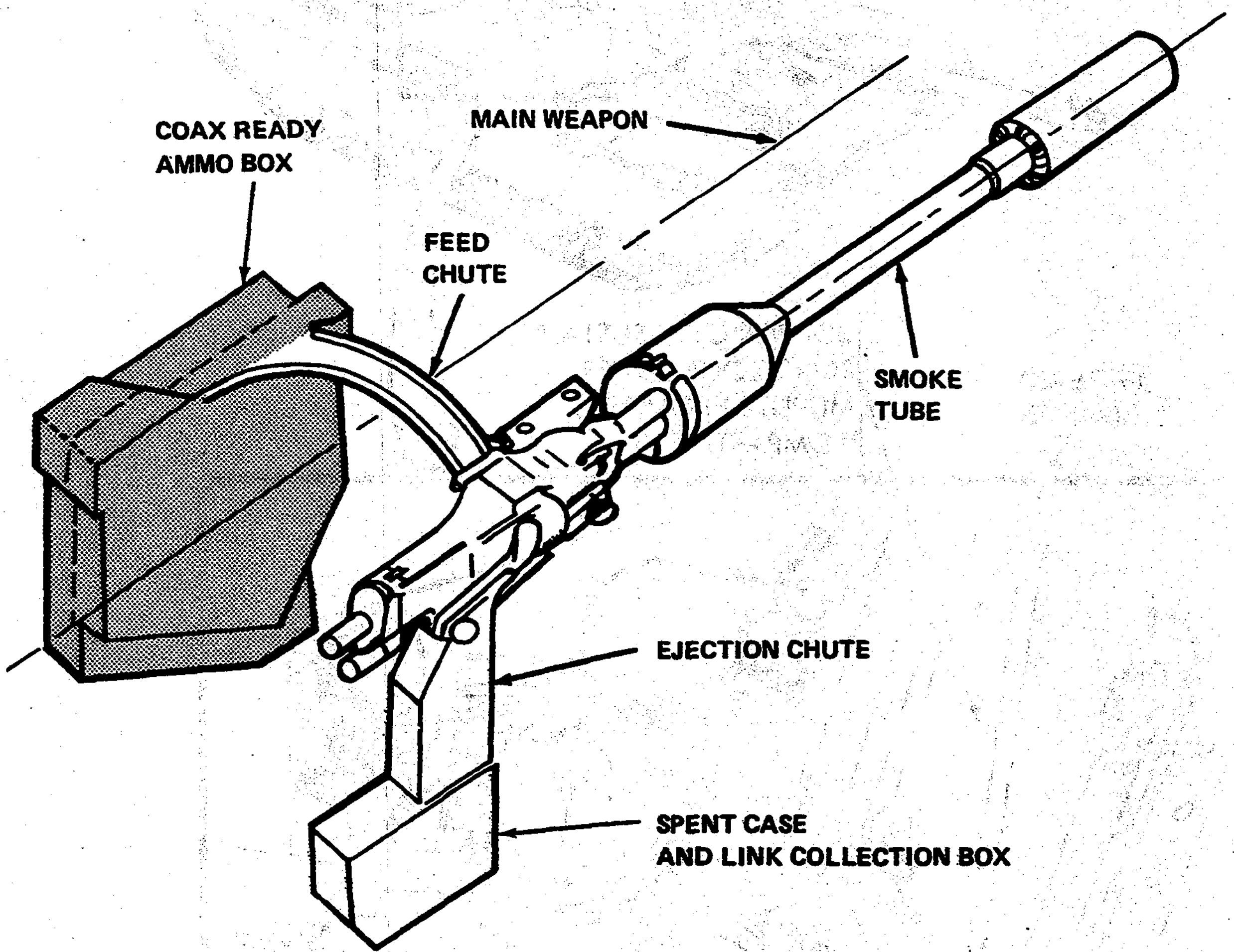


Figure 3-22. Coax Ready Ammunition Stowage

3.4.5.2 Main Gun and Mount

The 120mm, M256, main gun shown in figure 3-23 is mounted in a concentric hydrospring recoil mechanism, has a smooth bore tube, and has a sliding wedge breech. It is equipped with a bore evacuator and thermal shrouds, and is electrically fired. Stub case ejection and breech operation is automatic and supplied from recoil energy. The quick-change feature eases replacement of the tube. The Muzzle Reference Sensor (MRS) is bolted on the gun muzzle and requires no modification to the government furnished gun tube.

Gun support and alignment is maintained by two simple bearings spanning 29.5 inches. The gun is joined to the recoil mechanism using an adapter plate which is bolted to the

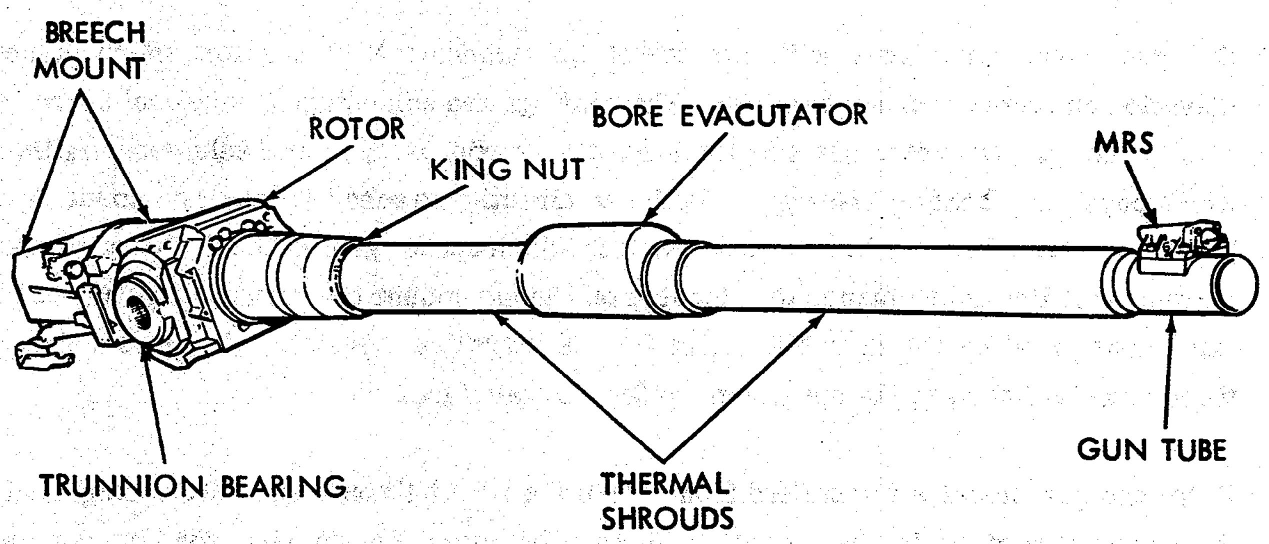


Figure 3-23. 120mm, M256 Main Gun and Mount

breechring. The adapter plate provides a 2.3 minimum safety factor. Optimum operating pressure during the 12 inch recoil provides uniform and minimal trunnion-bearing reaction. The trunnion bearing clearances are minimized by using pre-loaded, zero clearance, spherical anti-friction bushings. Minimum clearance has been designed between the trunnion bearing and its mountings (internal and external). The space required for the gun mount has been minimized using a cradle outside diameter of 19.75 inches and a length within the turret governed by the recoil travel plus solid height of the counter-recoil spring.

The cradle inside diameter is designed to accommodate the spring with adequate clearance to preclude failure to return to battery tendencies under all environmental conditions. The spring has been designed to operate at 112,000 psi maximum stress, a proven satisfactory value for achieving reliability with an anticipated endurance of 10,000 cycles. The counter recoil force, being sufficiently high for concern with respect to excessive shock loads during return to battery, is tailored by the counter recoil buffer to ensure tolerable shock levels.

The open system, gravity feed, self-venting, translucent plastic replenisher is mounted on the turret roof and it is connected to the recoil housing by two hoses. It has no moving parts and provides an instant visual indication of the oil level to the crew.

The gun mount interfaces with the turret by attachment to a rotor, which pivots in elevation on turret trunnion bearings. The bearings are self-aligning spherical bearings of high capacity. The rotor has apertures for the coaxial weapon and telescope, neither of which physically contact the rotor. Both are directly attached to the gun mount cradle. The rotor also mounts a fire-control resolver which senses gun position. Rotor elevation movement is limited by bump stops located on the gun mount that contact the turret. The gun mount provides the attaching point for the elevating cylinder. Also, a roof mounted tie rod can be linked to the gun mount to form a travel lock.

Rotor and gun mount are installed from inside the turret through the CWS opening so that the opening/aperture in the turret front need be large enough only for the gun tube, telescope, and coax machinegun, thereby increasing ballistic protection. The aperture clearance around the gun tube is shielded with armor plating. A water tight seal is also provided in the aperture to prevent leakage.

3.4.5.3 <u>Secondary Weapon Systems</u>

The coaxially mounted M240 machinegun (7.62mm) fires throughout 360 degrees of traverse and from -10 degrees to +20 degrees elevation. The commander's .50 cal, M2 machinegun can fire through 360 degrees of traverse, independent of turret position and from -10 degrees to +65 degrees elevation. The loader's 7.62mm, M240 machinegun is skate mounted on a rail to provide a 265 degree field of fire coverage to the left of the turret from -35 to +65 degrees elevation. Smoke grenades are fired forward of the turret covering a 120 degree sector.

Visibility is provided for the commander by an open-hatch, partially-open hatch or use of unity vision periscopes providing 360 degrees horizontal view. The loader has all around view when operating open hatch and his vision periscope rotates in his hatch to provide 360 degrees view from inside the tank. The loader's hatch will also accept the driver's night vision device for night time surveillance. The gunner has an area of view via the unity channel of the Gunner's Primary Sight GPS in the direction of fire. The gunner also has periscopic sights with 16 and 6.2 degree fields of view at 3X and 9.5X, respectively. The gunner's periscope display scene is also relayed to the commander via the commander's eyepiece extension.

The coax machinegun system shown in figure 3-24 is mounted on the main gun mount and moves in elevation and depression with the main gun. The system includes the 7.62mm machinegun, the machinegun mount, the ready ammunition box, the feed chute, an ejection chute, the spent-case and link collection box, and the smoke tube.

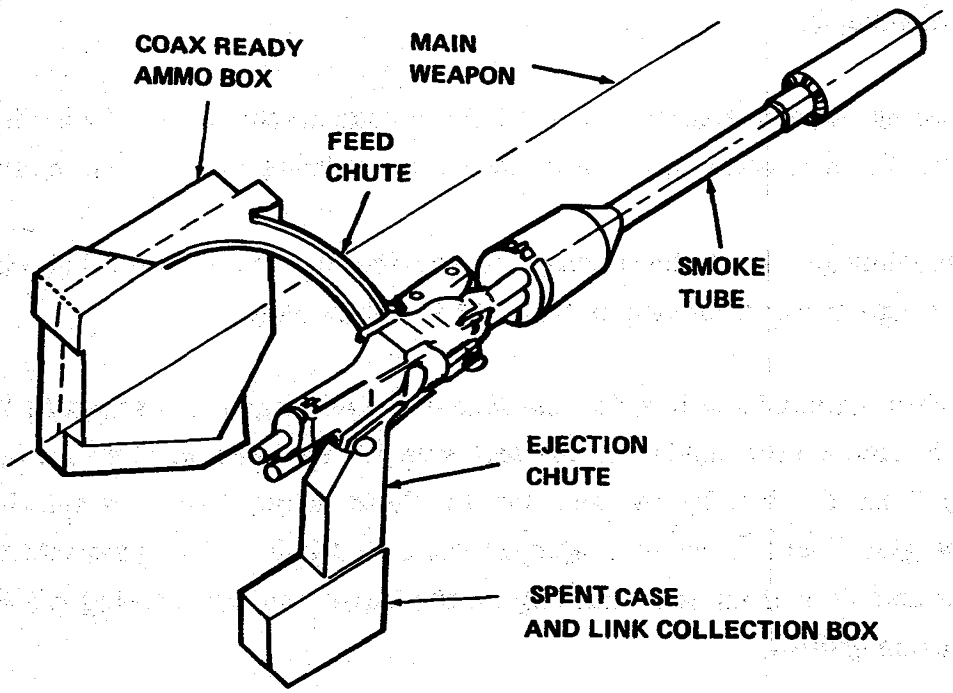


Figure 3-24. Coax Machinegun System

The machinegun mount consists of a cradle which bolts to the main gun mount and mates with the coaxial weapon mounting points. The coax weapon is mounted above and to the right of the main gun. This position improves the space usage of the turret since it is above the Gunner's Auxiliary Sight and permits the left side of the turret tunnel to be smaller while not increasing the right side.

The ready ammunition box consists of a spring loaded inner box inside an outer box. The outer box is attached to the left side of the main gun mount for easy access by the loader. Total ready ammunition capacity is 2,800 rounds. The spring loaded inner box raises the coax ammunition as the machinegun is fired to reduce ammunition belt pull force. A rigid feed chute with an anti-roll back device extends from the ready box to the weapon feed tray. Ejected cases and links enter a chute and are collected in the rigid box below the main gun. The box will hold approximately 400 ejected cases and links. The rigid construction of the box, as opposed to a bag, prevents jams due to collapsed walls, and permits the loader to move easily and quickly to discard the cases and links. A clear plastic window on the chute permits the crew to see when the box should be emptied. A smoke tube aids in directing toxic fumes due to firing to the outside of the turret during firing of the machinegun.

Deep-water fording requires sealing the hole for the coax machinegun. A plug is provided for this purpose. Before installing the plug, the coax machinegun must be removed.

The loader's machinegun is skate-mounted to provide the loader with 265 degrees of firepower converage at elevation angles from -35 to +65 degrees.

The 7.62mm ready ammunition box for the loader's machinegun is a standard 200 round field box that is placed on a holder at the left side of the weapon. The ammunition is pulled directly from the box by the gun and no chute is required. An ejection box is attached to the gun mount to receive ejected cases and links. This prevents the spent cartridge cases and links from accumulating on the turret roof or entering the air intake ducts or ventilation grilles.

For closed-hatch surveillance, a turntable in the loader's hatch mounts a ten inch wide adjustable mirror periscope, which is interchangeable with the driver's center vision periscope. When seated in position to load the main gun, the loader can use the periscope for sideward and rearward surveillance without difficulty. Swinging his seat to the rear, the loader can also survey the left-forward sector from a seated position. The loader's periscope provides good close-in vision in his sector of responsibility. The loader's periscope mount also has the capability of accepting the driver's night-vision periscope, less adapter. Night surveillance from the loader's station is enhanced over the driver's station due to the scope's higher position on the tank. For open-hatch observation, the loader has the option of standing on the turret basket floor, or the loader's seat to select eye-level, name-tag high, or waist-high surveillance positions.

The commander's .50 caliber, M2 machinegun or optional 7.62mm, M240 machinegun is mounted externally to the turret and can be aimed and fired from inside the turret. It is mounted to a rotary station which has a hatch, vision periscopes, a coupled periscope gunsight, and power and manual controls. The rotary weapon station structure is an armor steel casting with a hatch opening, attachment hubs for the hatch cover hinge, openings and protective covers for the six vision periscopes surrounding the hatch, and mounting surfaces for the sight and the gun mount support arms. A main drive gear is attached to the rim of the station. The main gear bearings employ plastic balls which have demonstrated outstanding performance in several similar applications. The advantage of these plastic balls is that they will not shatter or damage the bearing races in any impact due to gun fire or falling debris. The drive gear, machined onto a bearing race, protrudes through the turret mounting hole for engagement with the azimuth drive gearbox which is mounted on the turret roof adjacent to the weapon station mounting hole.

The commander's azimuth drive system consists of an electric motor, a gear shifter to select either power or manual operation, and pulleys for coupling the gear unit to the manual drive ring. The manual drive ring is approximately 29 inches in diameter and rotates concentrically with the weapon station at a ratio of ten to one. It is maintained in position by four rollers which are mounted to the turret roof. It is coupled to the azimuth drive gear with a reinforced belt drive that has a synthetic pile fabric on the drive side. The pulley surfaces in the drive ring and on the gear drive unit have attached synthetic fabric with short stubble bristles. This drive provides a no-slip operation.

The rates of motion achievable with the manual drives are approximately 10 degrees per second in azimuth and 6 degrees per second in elevation. Forces required are less than 15 pounds in azimuth and 10 pounds in elevation on level ground. At a 15 degree cant or pitch angle, the required force on the azimuth ring is 30 pounds maximum.

The smoke grenade launcher shown in figure 3-25 provides the tank with a means for evading the enemy and/or defending against antitank, optically guided missiles. When both grenade launchers are fired, they produce a 120 degree smoke screen 30 meters in front of the tank. This wall of smoke aids in the defense against optically guided missiles and helps evade enemy troops. The launchers, which are mounted externally on the turret, are aimed by rotating the turret.

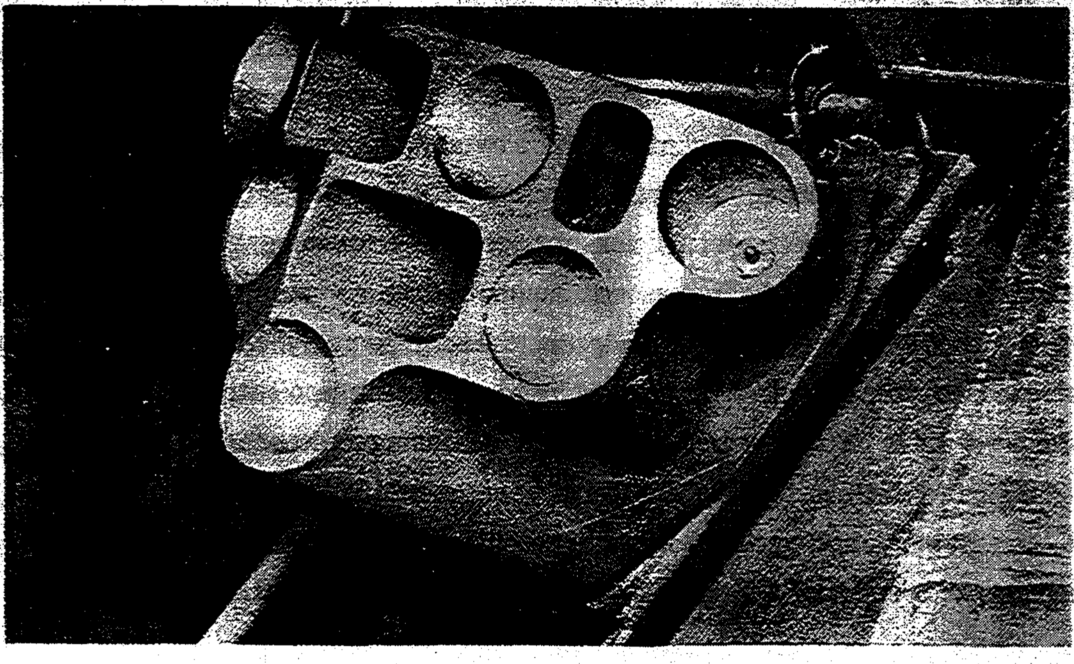


Figure 3-25. Smoke Grenade Launcher

Each launcher holds six grenades and is mounted on the left and right turret side wall forward of the stowage baskets and below the top deck level. One reload complement is stowed outside the turret. The grenades are electrically fired and contain the propellant as well as smoke-producing, red phosphorous pellets.

3.4.5.4 Commander's Weapon Station (CWS)

Major emphasis has been given to work space layout and equipment integration. The commander can operate seated, in any of three standing positions, and can move rapidly between these positions while maintaining command and control. The resulting configuration permits a high degree of flexibility. Figure 3-26 depicts the primary operating modes of the Commander's Weapon Station. In the seated closed hatch position, the commander can preset his seat height at a position that allows him to look directly into 1) the unity vision periscopes, 2) the .50 caliber, M2 machinegun sight, and 3) leaning forward, the Commander's GPS Extension (CGPSE). His bottom platform also includes a

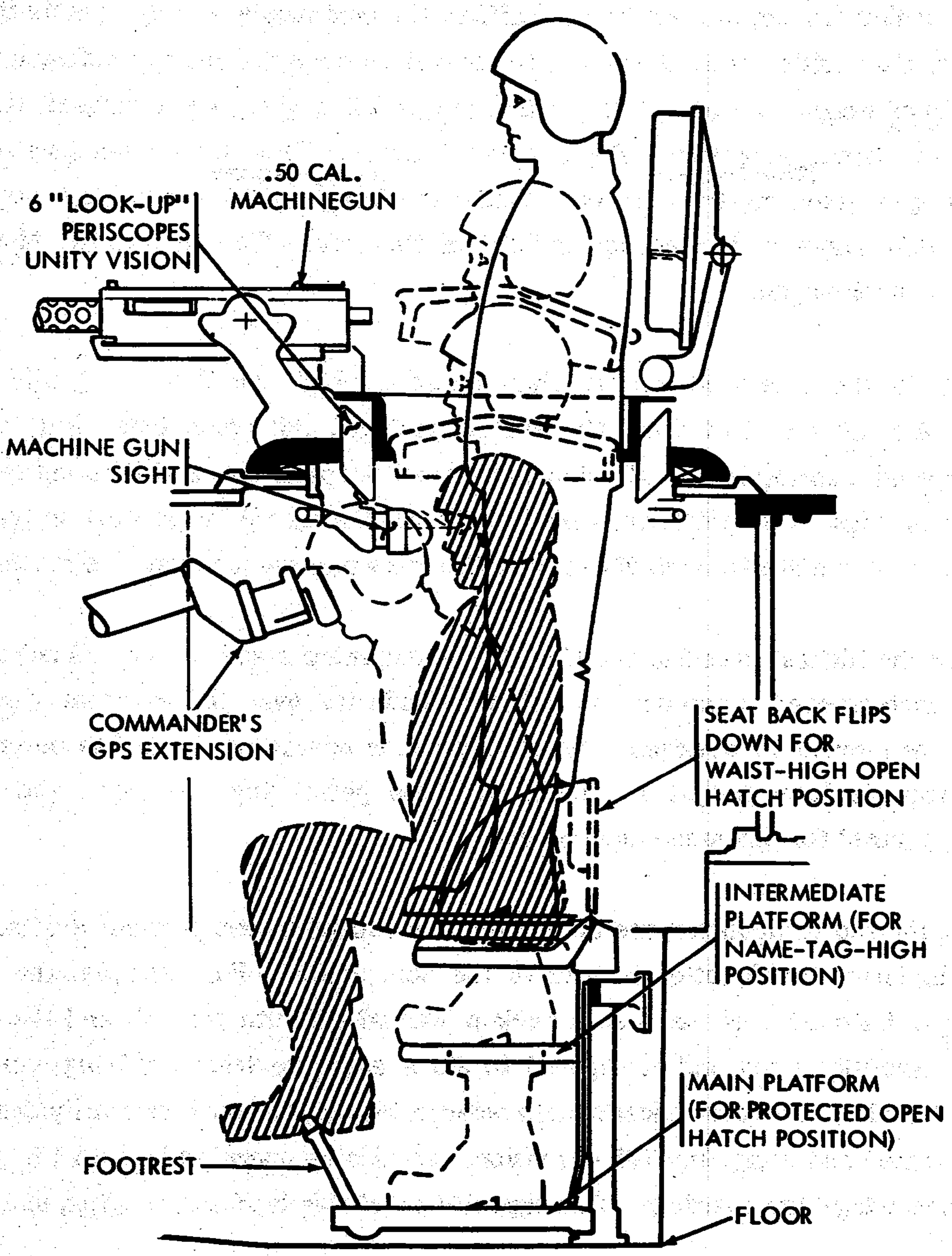


Figure 3-26. Commander's Station Operating Modes

convenient flip-out footrest for comfortable leg posture. Once initial individual settings have been made, no seat or platform adjustments are necessary in order to look into any of the optical devices. All major displays and controls including the control panel, main weapon control handle, azimuth power machinegun control handle, remote radio intercom switch, and manual machinegun controls, possess high visual and physical access.

For the standing protected open hatch position, the commander simply presets the bottom platform to the position that allows him to observe through the opening between the hatch and the top of weapon station. This position allows 360 degree vision while simultaneously providing overhead protection. For a quick transition from his seated position to the protected open hatch position, the commander need only open the hatch and stand on the platform while flipping the seat up and out of the way. This also allows him to view beneath the machinegun.

Movement to the intermediate standing, name-tag-high position is equally straightforward. Assuming a start from the seated position, the commander fully opens the hatch, steps on a spring loaded flip down intermediate platform, and flips his seat up and away from his legs. This platform, yoked to the previously set larger bottom platform, is positioned to let the 5th through 95th percentile crewman see just over the machinegun.

Finally, for the highest standing position, the commander stands on his folded-down seat back for unobstructed maximum open hatch visibility over his external weapon. In summary, the movement between each of these four operating modes can be undertaken with no seat/platform height readjustment, thus permitting the rapid and effective operation required for command and control.

Armament-related components are designed and arranged to complement available turret space, and address the functional needs of the commander. For example, the commander's weapon traverse ring, used as a backup manual azimuth control, and the elevation crank are carefully sized and configured to allow accurate tracking/firing capability in the manual mode. The commander's main weapon handle, although primarily designed for use while seated and using the GPS extension, can also be operated in both the protected open and name-tag-high positions. This capability includes tracking, ranging, and firing.

The Commander's Weapon Station (CWS) provides the commander with versatile modes of surveillance. He has 360 degrees of vision horizontally in all modes without rotating the station. The full-open-hatch mode provides the greatest clarity and freedom for rapid scanning. A partially opened hatch position provides much of the flexibility associated with the full-open-hatch mode and will provide overhead armor protection from shrapnel or small arms fire. In the closed-hatch mode, six unity vision periscopes are employed. A periscopic sight provides a three-power telescopic view that is trained on the target by rotating the weapon station and elevating the weapon. This instrument is coupled to the commander's weapon mount and provides an accurate sight for the weapon, moving in elevation with the weapon from -10 degrees to +65 degrees.

The commander's .50 caliber machinegun (or optional 7.62mm machinegun) is mounted on a rotary turntable so that the weapon can be aimed to any azimuth position. The commander's hatch is located in the center of the turntable with its principal hinge at the rear. A secondary hinge point at about the center of the hatch cover allows it to tilt forward after opening about 30 degrees. This arrangement lifts the rear edge of the cover, as well as the front, so that the commander, with his head up in the domed cover, has a slit for open vision in all directions. This partially opened position provides the commander with overhead armor protection. Six vision periscopes surround the hatch; the armor skirt around the hatch cover provides additional protection from small arms fire.

The full-open hatch mode of surveillance provides the commander with the best viewing and greatest flexibility for seeing in all directions. The open hatch cover at his back will provide small arms protection to shoulder height. The armor cover over the vision periscopes and the hatch hinge provides small-arms protection to elbow height. The commander can elect to use this mode with different positions, from completely inside the turret watching the sky and observing through vision periscopes, up to a height as limited by safety or his ability to reach the controls.

When the hatch is fully closed and the hold-closed latch is opened, the equilibration system will raise the hatch cover to the partially opened position. Changing to the full open latch position requires release of the hold-open latch and a simultaneous push with the other hand of about 40 pounds. Closing the hatch cover from the partially opened position requires three operations. The hold-open latch is released while pulling downward on the hold-close latch handle with the left hand (about 40 pound pull); the yoke latch is released with the right hand and additional downward pull is exerted on it (about 40 pounds); and lastly the hold-closed latch is rotated to the latch position as the hatch arrives at the closed position.

When changing from the closed hatch to the partially opened mode of operation, the commander must raise his head and shoulders approximately ten inches. Changing from partially opened to full open requires another 10 to 12 inches.

The hatch system includes the hatch cover, the hold-closed latch, the yoke latch, the yoke, the trunnion equilibrator, and the hold-open latch. The hatch cover is a domed armor steel casting with a skirt around it, which provides additional protection to the commander from small arms when operating in the partially opened mode. The hold-closed latch is a simple lever with a handle that also serves for pulling the cover to close the hatch. The yoke is a steel casting which acts as a lever arm between the main trunnion and the secondary axis, permitting the hatch cover to remain nearly horizontal when in the partially open position. The primary trunnion employs torsilastic and torsion leaf springs for equilibration of the hatch cover weight.

The trunnion has two features to prevent pinning by small arms fire. The tube which forms the axle can either rotate with the hatch cover or be stationary with the anchor. If a small arms projectile should penetrate the trunnion it can still rotate. Also a thick plastic washer is employed between the anchor and the yoke so that a projectile in that region will not lock two steel parts and prevent opening the hatch.

The commander's station controls shown in figure 3-27 provide the means by which the commander can slew, track, and position his machinegun with a minimum of effort in both the powered and manual modes. The control simplicity also allows the commander to maintain an optimal fighting station while directing the crew. The powered system is basically a rate servo system that utilizes a unique method of controlling the input rate. The system is electrically powered by the 28 volt vehicle electrical system. A permanent magnet torque motor drives the station in azimuth. This type of motor provides high torque at low speeds, fast response due to low self-inductance, and a linear voltage/speed characteristic. Tachometer feedback is utilized in the azimuth axis to overcome frictional variations in the mechanical drive and allow smooth tracking and accurate positioning of the weapon. The servo amplifier which generates the drive signal for the motor is small, totally encapsulated, and multi-sourced.

The amplifier is operated in a voltage feedback mode which results in an output motor speed proportioned to the input voltage. The azimuth rate input control is contained in the thumb control handle which is connected to a coil cord for ease of use by the commander. Left or right force on the thumb controller creates a phase sensitive electrical signal proportional to the input force. This signal is used to produce a directional rate command input to the weapon station.

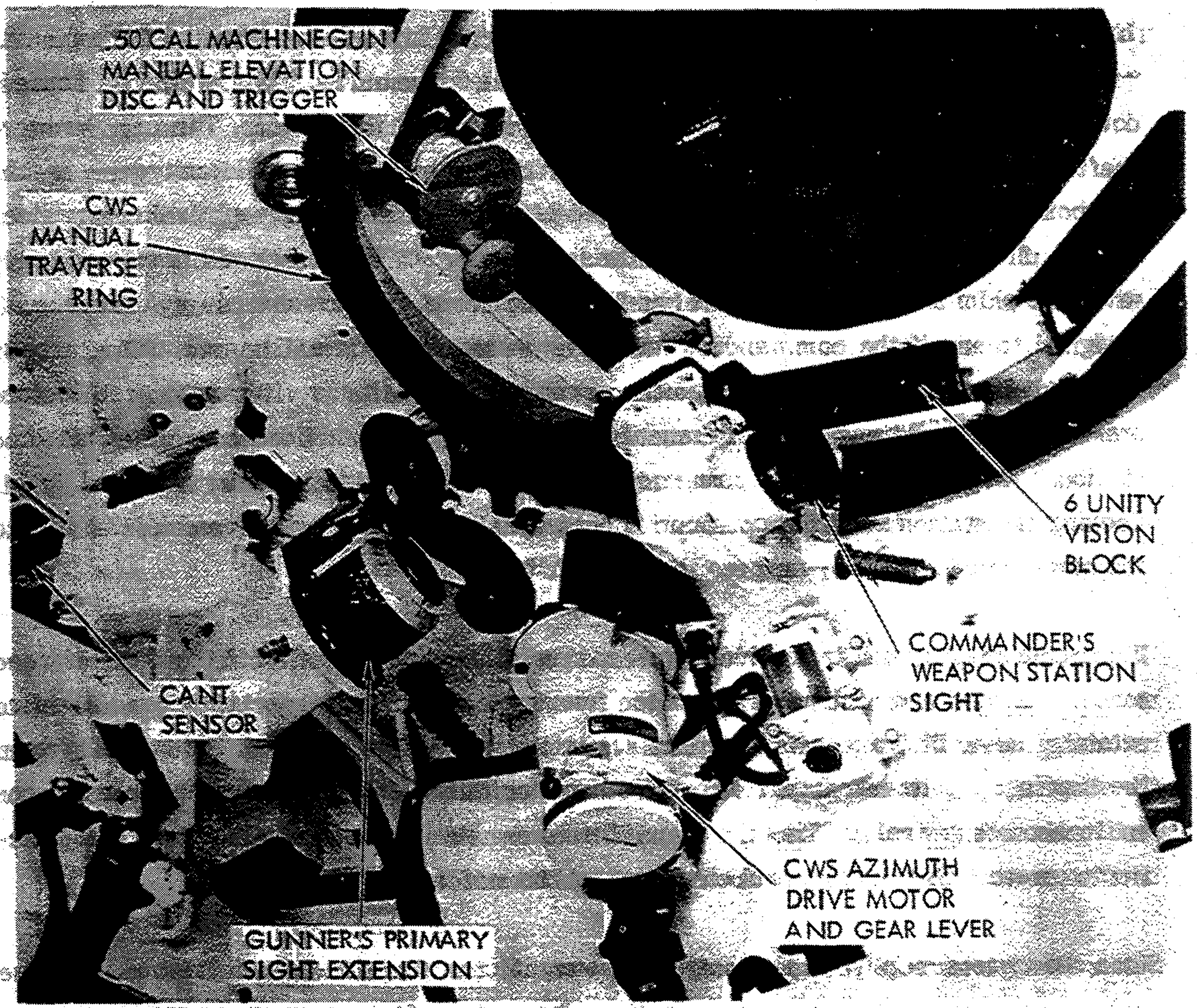


Figure 3-27. Commander's Station Controls

The effectiveness of the commander's machinegun is largely dependent on how quickly he can acquire a target and continue to track it smoothly at low speed, or accurately position his weapon on a stationary target. These requirements are met with the power-control system while operating almost without noise. The system can smoothly track targets at one mil/sec. Acceleration capability exceeds one rad/sec^2 which gives the system excellent response to rate commands. Low-speed resolution allows precise target laying within a fraction of a mil.

The azimuth drive consists of a cylindrical housing that interfaces with the CWS azimuth gearbox. The housing contains the motor and brake assemblies. The motor is a housed double-shafted torque motor with an internally mounted tachometer. The upper motor shaft is externally splined and meshes with the internally splined input gear on the gearbox. The slotted lower shaft is keyed to the fail-safe (spring applied) brake which mounts directly on the motor. The brake is normally "on" (applied) and is released only when the palm switch on the control handle is depressed. To prevent damage, the brake is designed to slip if the commander's machinegun sustains a lateral impact. The gearbox mounted gearshift allows either power or manual operation by disengaging the motor brake assembly and engaging the manual traverse ring mounted concentrically with the station. The gear ratio in the power mode is 285 to 1 and in the manual mode is 10 to 1. Locking the station in a fixed position is accomplished by moving the gearshift back into the power mode, which re-engages the fail-safe brake.

Electronic shaping circuits provide increased resolution at low speeds for the thumb force sensor. Smooth and continuous operation from tracking to full slew rate is possible while retaining the ability to command minute variations in the tracking rate. The outputs from the shaping circuits are amplified by the servo amplifiers which also sum the force sensor and tachometer signals. The servo amplifiers are wired in a current-limiting configuration to protect their own internal circuitry and the motor.

Since the system requires only electrical power, it can function without the noise of the engine running or a hydraulic pump cycling. The commander can survey an area or target completely independent of the turret or hull. This provides the other crew members uninterrupted surveillance of their respective target areas.

3.4.5.5 Gunner's Station

The combat tasks of surveillance, target acquisition, and target engagement in a moving tank have received primary emphasis relative to design of the gunner's station. The fire control equipment, available work space, and the gunner have been integrated in a manner that optimizes system performance requirements of high hit probability and rate of fire. The gunner's tasks have been simplified by automating and/or combining the design of the sight, laser rangefinder, computer, LOS stabilization, and other fire control related devices. Some examples include the elimination of most individual subsystem power switches, automatic continuous lead, and range indicators integral to the periscope display scene. This simplification and integration shown in figure 3-28 is reflected in the gunner's interaction with his equipment during a typical target engagement. He need only check the selected round on the gunner's primary sight panel, view the target and its range in the eyepiece, and manipulate the control handles.

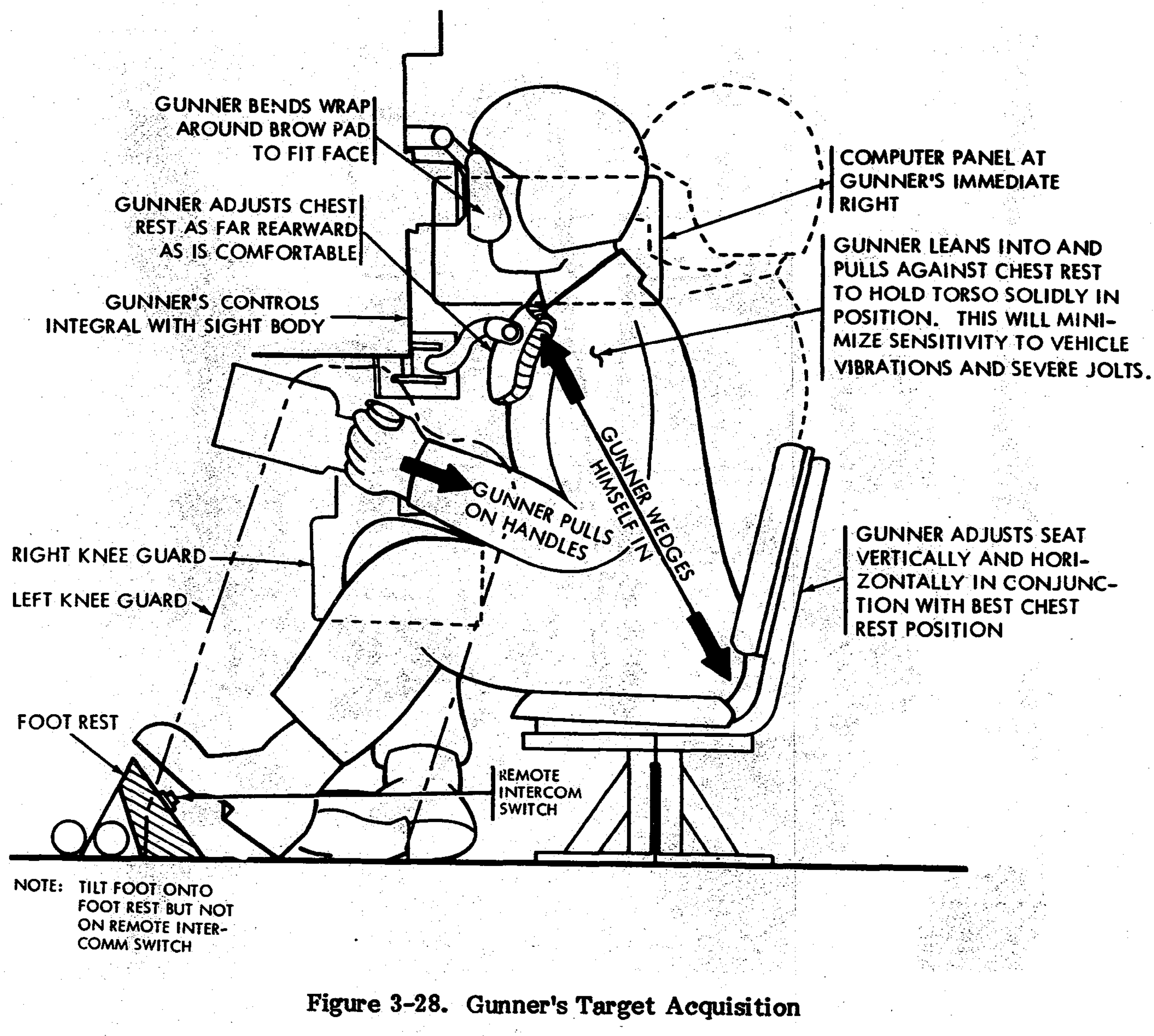


Figure 3-28. Gunner's Target Acquisition

The gunner's seat controls allow the 5th through 95th percentile arctic clothed crewman to adjust his position relative to the Gunner's Primary Sight (GPS). The seat, the gunner's station GPS eyepiece, and the control handles shown in figure 3-29 provide the most comfortable body position for the task of gunning. No seat readjustments are needed to use the Gunner's Auxiliary Sight (GAS). Although left and right knee guards necessarily limit the amount of knee and foot space, the left knee can be moved to the right to obtain additional room for use of the manual elevation hand pump. In addition, vehicle ingress and egress has received thorough consideration, with movement times to and from the gunner's station being achievable in approximately three seconds. On equipment materiel (OEM) accessibility reflects a convenient arrangement and protection from abuse of these various items.

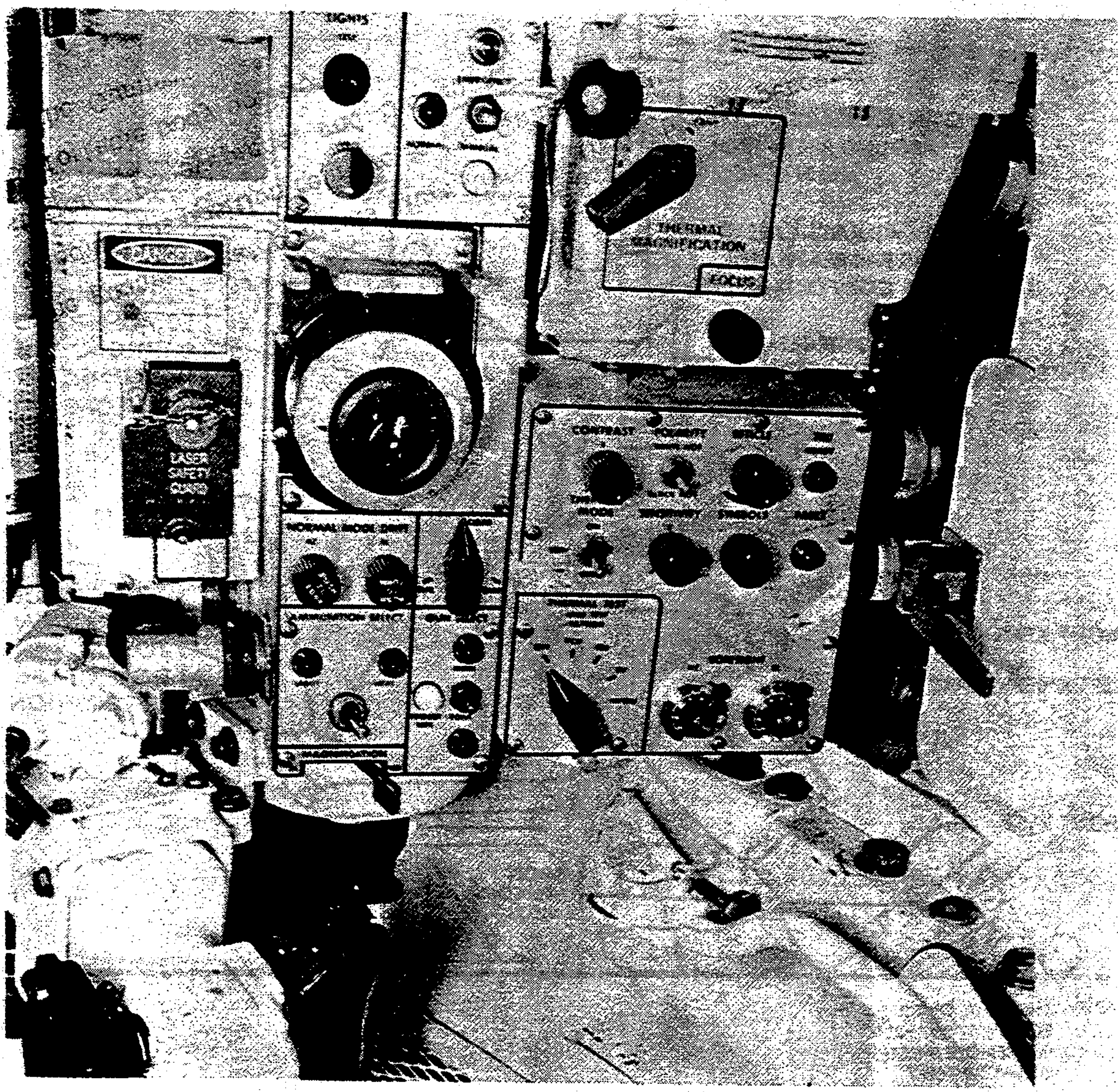


Figure 3-29. Gunner's Panel and Controls

The adjustable chest rest, which has been proven under extended severe environment test circumstances, plays a significant role in the steadying of the gunner's upper torso during high mobility operations. This guard folds out of the way when not in use. The formable wrap-around GPS browpad prevents head movement under these conditions. The aforementioned left and right knee guards protect the gunner's arms and legs providing the gunner with psychological security to allow total concentration on his target once an engagement has begun. For gunning on the move cross-country, the gunner's knee guards, chest rest, control handles, seat and brow pads all become body positioners, restraints and braces necessary to maintain control of the gun and keep the eye steady in the sight.

The Ballistics Computer and its control panel have been designed for simplicity and ease of operation. Self tests, manual inputs, zeroing, and boresight adjustments can be made with minimum training. The Computer Control Panel (CCP) allows for both zeroing of the muzzle reference system and selection of subtypes of ammunition within a general ammunition type e.g. APFSDS M827, APFSDS M829. All controls that are typically used in a nominal target engagement have been placed in easy reach on the GPS panel.

3.4.5.6 Loader's Station

The loader's station shown in figure 3-30 represents the physical and functional integration of personnel and equipment. Emphasis has been placed on minimizing the complexity of work required by the loader, and facilitating his functional tasks in the high-mobility environment. The loader sits on a six position seat that has vertical adjustment capability, allowing him mobility and access to ready rounds stowed in the bustle, and to the main gun breech. His three-point stance is the key to his ability to withstand severe vehicle motions without losing his balance. The seat backrest provides general riding comfort and can be quickly disconnected and stowed at the loader's option if additional elbow clearance is desired during the loading sequence. Bracing is provided for general riding conditions by means of a grab handle conveniently located on the left side turret interior sloping wall.

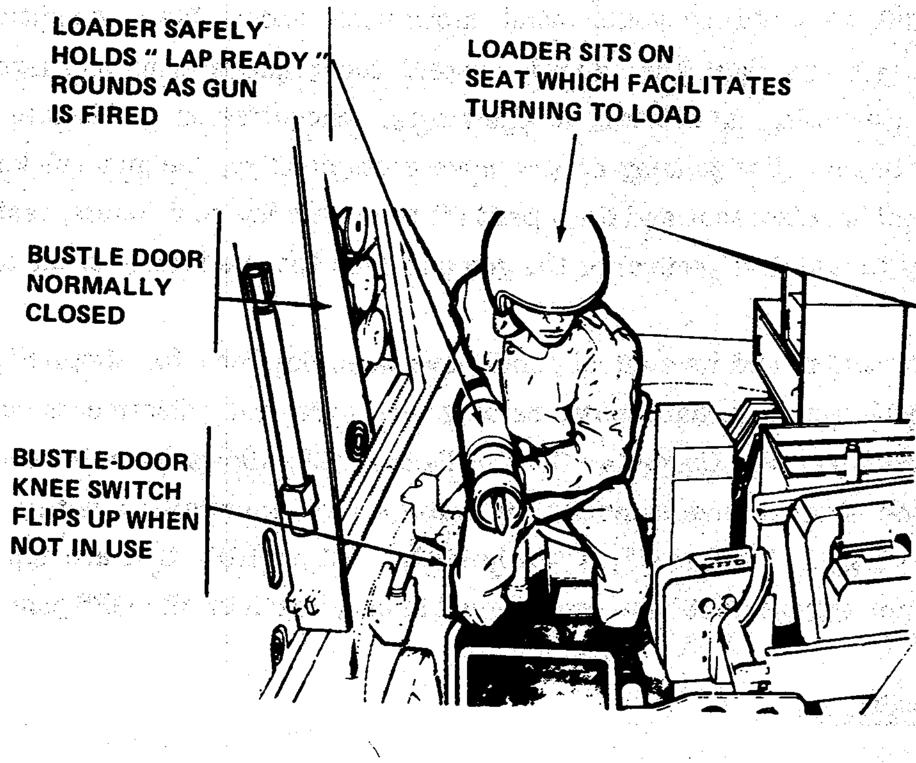


Figure 3-30. Loader's Station Configuration

The loading sequence and time is shown in figure 3-31 and should be referred to along with the following description. The accompanying time line is within the abilities of the loader.

(Frames 1 and 2): Initially, the loader takes a semi-seated position and turns toward the ready round bustle door, with the seat facilitating this movement. He then opens the bustle door by applying pressure to the large knee paddle switch mounted just below the turret race ring. The paddle can swing up and lock in a "safe" position when not in use. The bustle door opens in approximately 1.0 second by sliding to the loader's left, revealing 17 ready rounds. The loader reaches into the compartment, releases the holding tab with his thumb, and extracts the round with his right hand.

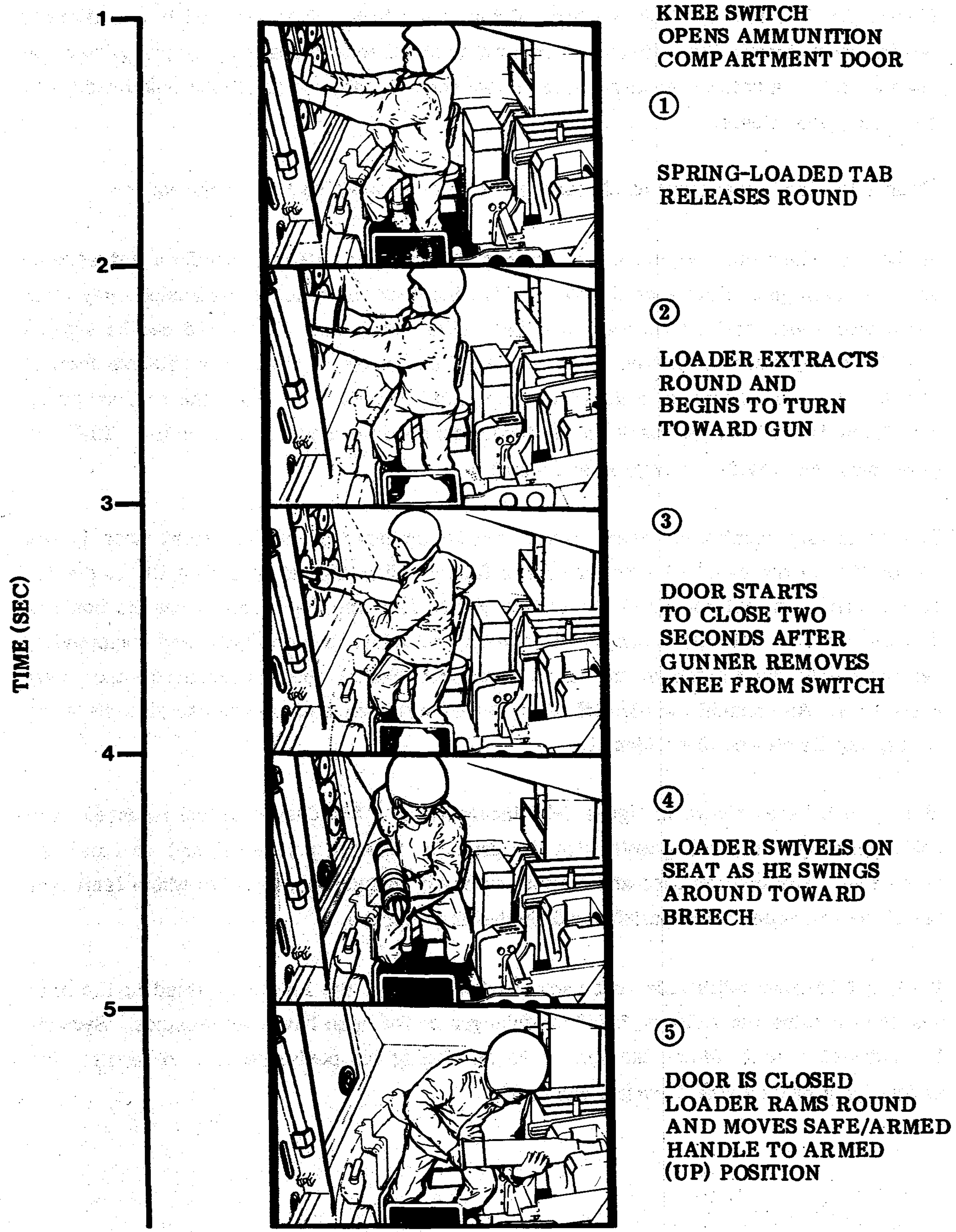


Figure 3-31. Loader's Main Gun Loading Sequence

(Frame 3): The loader brings the base of the round to his right side and in a continuous motion, turns toward the main gun. This turning movement draws his knee away from the knee switch in a natural manner. After a two second delay (to facilitate round removal), the bustle door closes.

(Frame 4): The loader turns on his seat and is now in a position to load the round.

(Frame 5): The round is rammed into the chamber and the safe/arm handle is actuated to arm the main gun. Note that the padded left shoulder guard keeps the loader away from the breech recoil path without slowing the loading sequence. This guard can be stowed out of the way when not in use. He now faces the bustle, in position to retrieve another round. The padded left knee guard protects the loader's knee from the breech during recoil, and is easily pushed back on the three round ammo rack when not in use. The knee guard also can provide leverage when loading.

The previously mentioned, ready round, bustle ammunition compartment door is not inoperative in the event of a power source failure. For manual operation the loader (or commander) can pull the quick disconnect pin to free the door from hydraulic control. The unpowered, semiready round, bustle door is accessible to both loader and commander, requiring only the release of the latch to permit manual door movement to the ready round area. An ammunition identification device has been incorporated to give visual as well as tactile stowed round identity.

The loader's hatch shown in figure 3-32 incorporates a 360 degree swivel mounted wide angle periscope (interchangeable with the driver's forward periscope) and an improved hatch seal. The loader's seat and support assembly include two features which facilitate use of both the open hatch position and the hatch periscope.

First, a fold-down adjustable seat-back platform allows the loader to stand in the best position for using the 7.62mm, M240 machinegun or for open-hatch surveillance. Second, the adjustable seat allows the loader to sit facing his periscope and to monitor his assigned sector (left side, forward, and rear).

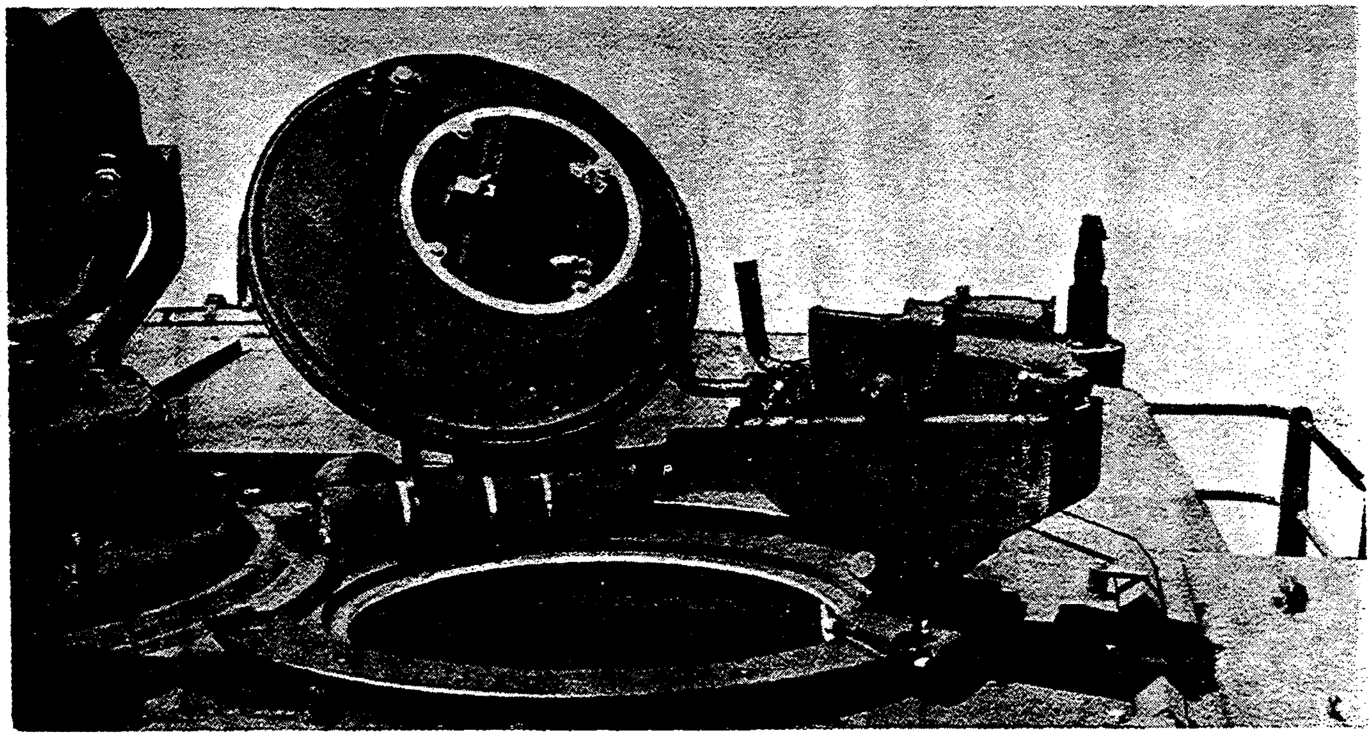


Figure 3-32. Loader's Hatch

The loader's panel shown in figure 3-33 is located to the left of the loader where it can be easily reached by the loader and viewed by both the loader and the commander. The gun/turret drive control locks out turret and gun stabilization hydraulics preventing powered turret movement relative to the hull and gun elevation movement. Placing the gun/turret drive control in the manual position allows the loader to safely remove main gun ammunition from the hull racks and allows maintenance personnel to work safely on turret systems with powered movements of the gun and turret disabled. Two indicators on the loader's panel show the condition of the main gun firing circuit ("armed" or "safe"). The main controls for the AN/VRC-12 or AN/VRC-64 radio receiver/transmitter, including the KY-57 scrambler, are located for operation by the loader. An elevation decoupler circuit is provided for use when clearing a jammed coax machingun. This circuit is activated when the loader places the G/TD control switch in the uncoupled position. If below zero degrees elevation, the gun will automatically move to the zero degree elevation level and will be decoupled from the stabilized sight during servicing of the coax machinegun.

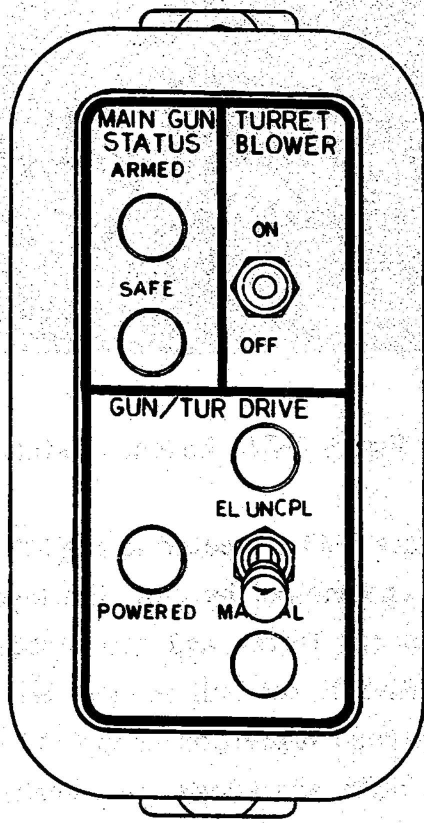


Figure 3-33. Loader's Panel

3.5 FIRE CONTROL

3.5.1 General Description and Function

The fire control system consists of all equipment which is provided for target sighting, ranging, aiming, and firing the 120mm, M256 main gun, the 7.62mm, M240 coaxial machinegun, the commander's .50 caliber, M2 machinegun, and the loader's 7.62mm, M240 machinegun. The general arrangement of the major fire control components and their approximate configuration is shown in figure 3-34.

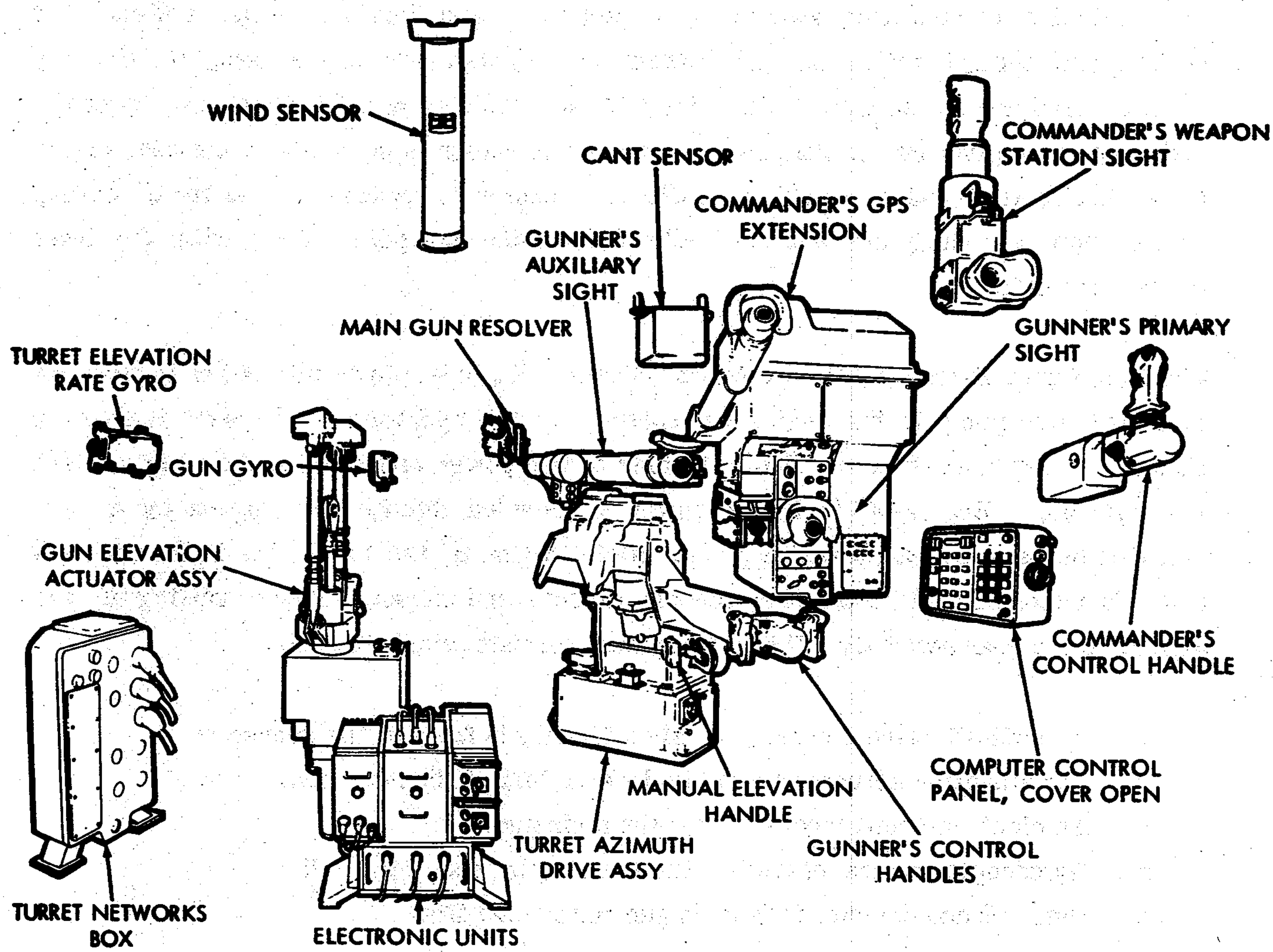


Figure 3-34. Fire Control System Components

The primary optical sighting instruments are the Gunner's Primary Sight (GPS) and the GPS extension to the commander. The GPS is mounted to the upper turret structure and incorporates servo-positioned reticles for complete ballistics solutions with day and night vision imaging. It is linked in the elevation axis with the main gun through resolver follow-up electrical devices. The laser rangefinder transceiver, the thermal night vision subsystem, and the gyro-stabilized line-of-sight platform are integrated within the GPS. The sight is ballistically protected with armor steel doors, over the objective opening, and are operable from inside the turret. The gunner also has an auxiliary sight (GAS) affixed directly to the main gun mount. The commander has a three-power fixed focus periscope for general surveillance and for firing the weapon mounted in his station.

The ballistics computation system is an accurate and flexible digital system that continuously controls reticle and gun offsets. It consists of the digital computer memory processor and associated input/output devices within an electronic unit mounted under the main gun and a gunner's control panel. A crosswind sensor is mounted at the rear of the turret bustle roof and a pendulum static cant sensor is located at the turret ceiling center, both of which are automatically fed to the computer along with the laser rangefinder data.

The Gun/Turret Drive (G/TD) is electrohydraulic. Engine-on hydraulic power is provided by a hydraulic pump in the engine compartment. The hydraulic fluid enters the turret through a slipring at the turret/hull interface to two power valves in the manifold beneath the main gun. Engine-off hydraulic power is provided through the slipring by a hull-mounted battery driven hydraulic pump. Stabilization of the turret/gun in the azimuth plane is accomplished through gyroscopic sensors and servocontrolled valving in the azimuth drive gear assembly. The G/TD system consists principally of:

- An azimuth drive assembly, located directly in front of the gunner.
- The elevation actuator assembly, located left of the main gun.
- An electronic unit located under the main gun.
- Gyroscopic sensors located on the turret, gun, and in the hull.
- Gunner's and commander's main gun control handles.

The primary function of the fire control system is to aim and fire the main gun with accuracies to provide the specified hit probabilities. Figure 3-35 depicts the major functional interfaces between components which are required to accomplish the system's primary function of main gun control. This figure also provides an overview of the fire control system which will aid the understanding of hardware and performance.

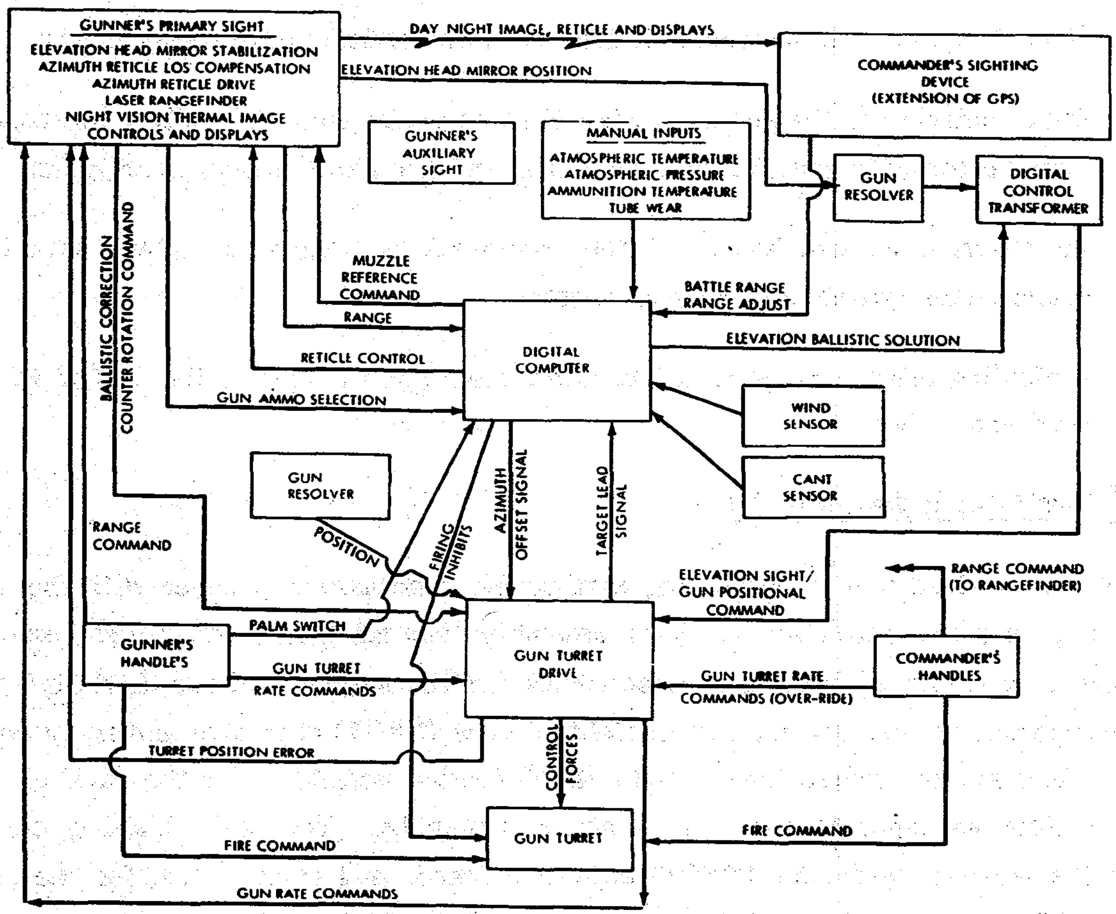


Figure 3-35. Fire Control System Functional Diagram

Overall design of the fire control system includes a substantial amount of redundancy to provide for survivability and fightability through alternate modes of operation if the primary system becomes damaged during combat. Examples of this redundancy include:

- Commander can use the GPS through the GPS extension if the gunner is incapacitated.

- Gunner's Auxiliary Sight can be used if the GPS becomes inoperable.

- o GPS directly slaved to the main gun in elevation if the stabilization system fails.
- o Manual elevation and traverse of the main gun if both turret power and auxiliary hydraulic power are lost.
- o Computer controls provide for early operator identification and nulling of malfunctioning inputs.
- o Manual inputs to the computer if desired in lieu of automatic sensor inputs.
- o Dual controls for the gunner, to include two power control handles, two parallel laser buttons, two parallel palm switches, and two parallel weapon triggers.
- o An override control handle at the commander's station, complete with laser button, palm switch, and weapon trigger.
- o A blasting machine is provided to allow main gun firing with the loss of vehicle electrical power.

3.5.2 Gunner's Primary Sight (GPS)

The GPS is comprised of a main housing casting and head assembly cover with the laser rangefinder, eyepiece assembly, headrest assembly, control panel assemblies, azimuth mirror drive assembly with the servoelectronics for the azimuth mirror drive and gyro reticle compensation electronics, narrow field of view (NFOV) objective and relay optics with the filter-shutter wheel, line-of-sight (LOS) cradle assembly, and the parallel scan thermal system as separate "bolt on" modular assembly. The main housing casting contains the wide-field-of-view (WFOV) objective lenses and relay optics for the commander's GPS extension. The modular construction of the GPS facilitates both producibility and maintainability. Each module can be separately manufactured and tested to individual specification requirements prior to installation. The laser rangefinder can be replaced in the vehicle without special tools and without destroying the integrity of the pressurized optical system. Conveniently located inlet valves permit easy access for periodic nitrogen purging and charging of the GPS. Removal of the GPS is accomplished from outside the vehicle with the only prerequisite being the removal of the ballistics cover, mounting bolts, headrest assembly, and disconnecting the commander's GPS extension and electrical harnesses. The eyepiece and headrest assemblies are interchangeable with the ones in the commander's GPS extension.

3.5.2.1 Optics

The Gunner's Primary Sight (GPS) shown in figure 3-36 provides a wide range of daylight vision alternatives. Unity power vision can be used for close-in surveillance and during slewing operations with a field of view of 18 degrees horizontal. The head mirror is stabilized in elevation and is a common element in all GPS systems. The daylight sight provides a dual power capability. A wide angle mode for area surveillance and a high magnification mode for target identification and gun laying. The high magnification mode has a magnification of 9.5 power and field of view of 6.2 degrees. The wide angle mode has a magnification of 3 power and a field of view of 16 degrees. The high power sight has a resolution of 50 cycles/mil for high contrast targets and 30 cycles/mil for low contrast targets. A + 2, - 6 diopter adjustment is provided in accordance with normal design practice. The daylight sight has an exit pupil diameter of 6mm and a clear eye distance of 25mm.

3.5.2.2 Elevation Head-Mirror Module (LOS system)

The elevation head-mirror module is a key element in the line-of-sight stabilization system which contains: (1) a two axis gyro and associated capture-loop electronics, (2) drive motor, (3) multispeed resolver, (4) d.c. tachometer, (5) solenoid brake, and (6) a unique aluminum head mirror shown in figure 3-37. Sight stabilization in elevation and turret stabilization in azimuth (using signals from the two-axis gyro) is utilized. The azimuth gyro reticle compensation system essentially azimuth stabilizes the reticle and provides performance substantially equal to that of a two-axis line-of-sight stabilization system.

The two-axis gyro provides inertial-grade body fixed signals for the head mirror in elevation and the turret in azimuth. Elevation rate signals from the gyro are processed in the LOS electronics unit to develop drive signals to the motor which provide a motion counter to vehicle motion and thus provide a stable sight pattern in elevation. Vision is accomplished by using a one-piece aluminum mirror with an optical quality replicated surface. This mirror provides a surface large enough to reflect day/night, unity, and laser light. Electrical signals from the resolver provide space stabilized reference signals to the gun. In the non-stabilized emergency mode of operation, the head mirror is positionally slaved to the gun using the same resolver network.

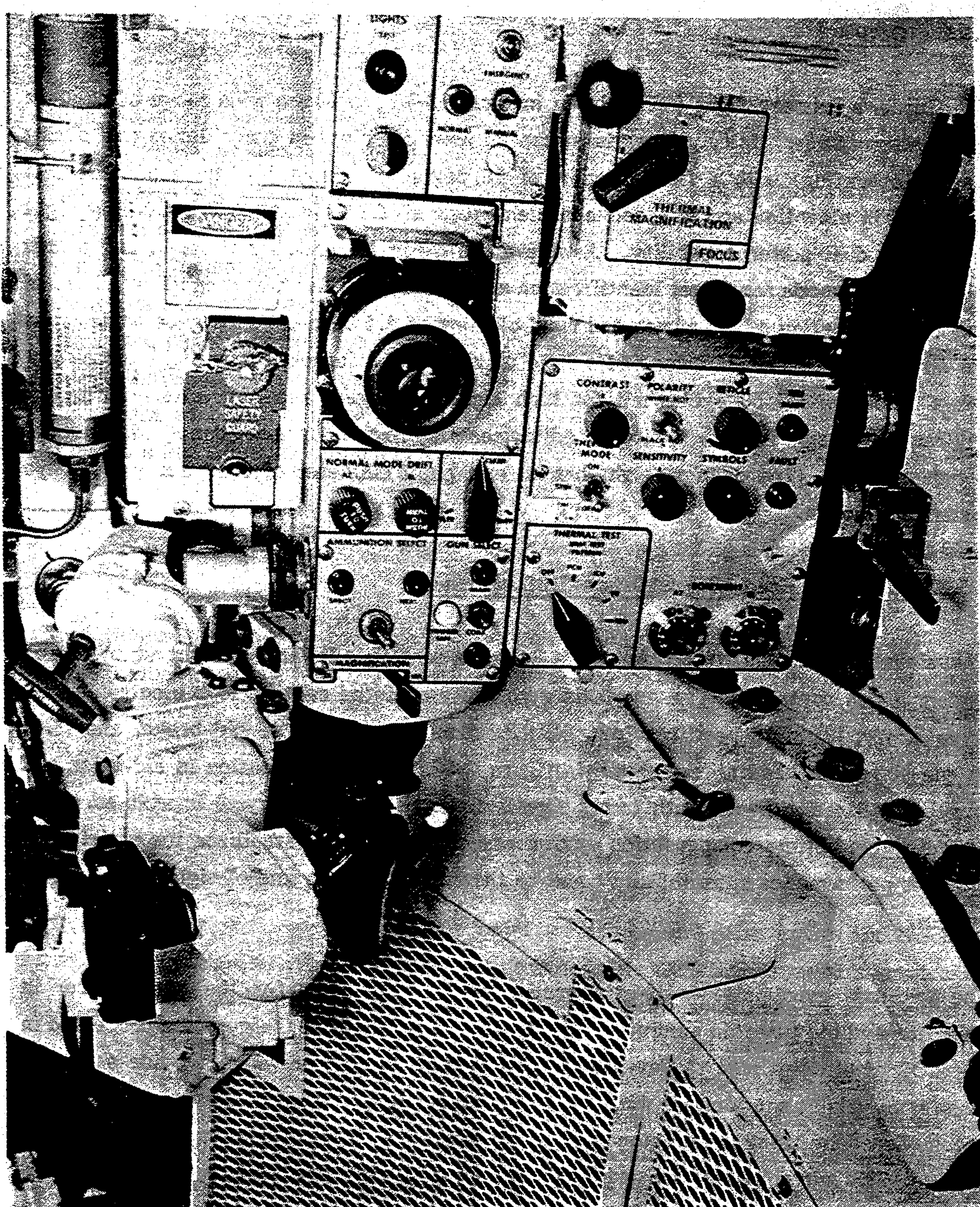


Figure 3-36. Gunner's Primary Sight Panel

3.5.2.3 Reticle Projector and Azimuth Drive

Figure 3-38 shows the overall functional concept of the gunner's reticle projection and azimuth reticle control. This system converts the total azimuth ballistics solution offset generated by the computer into an accurately deflected reticle in the gunner's field of view. The reticle source is located in the laser rangefinder where the reticle beam is permanently alined with the laser beam. A movable dichroic beamsplitter reflects the invisible (one micron) laser light toward the target and partially transmits the red reticle light. The reticle beam is returned along the same path by a retroflector and is partially

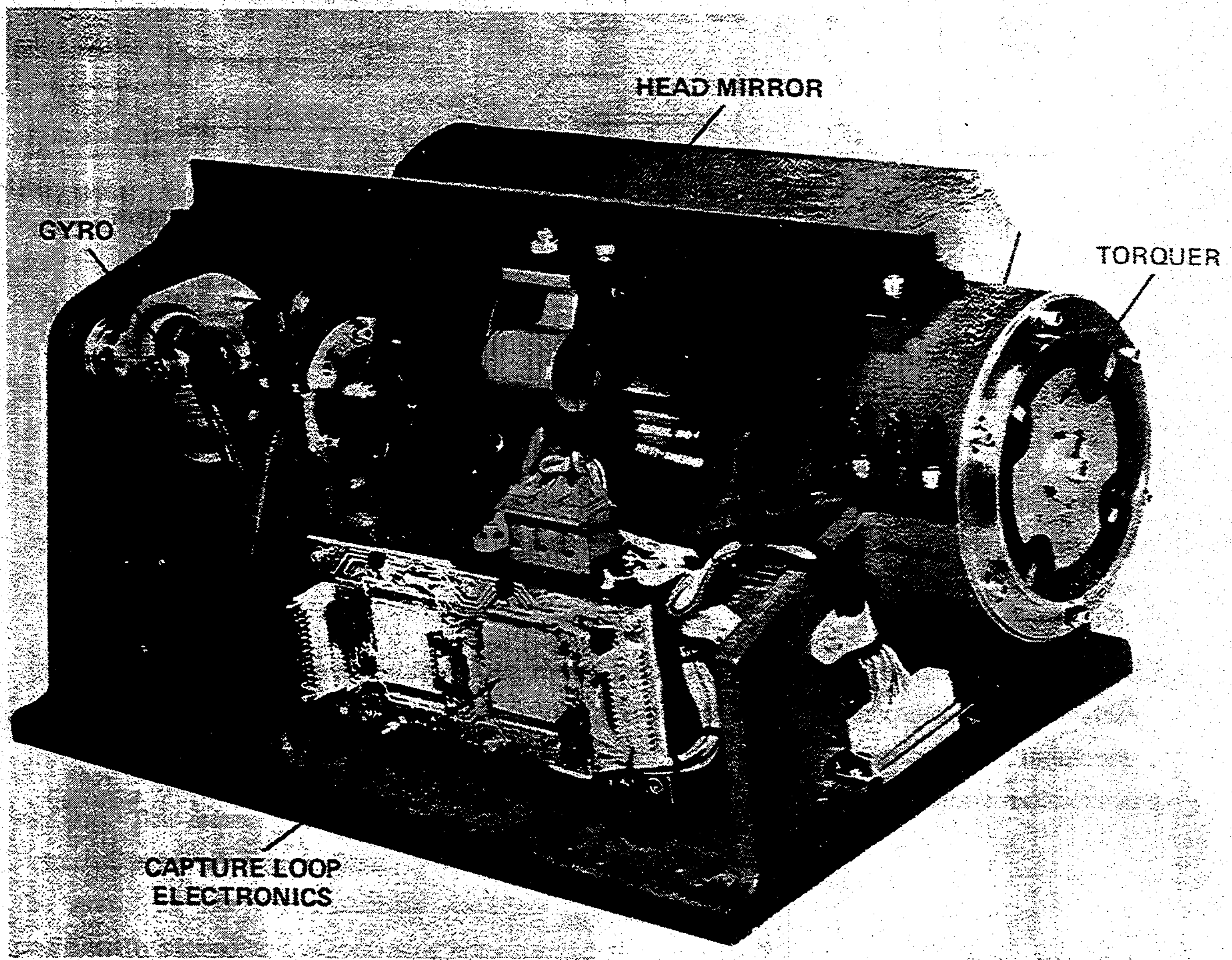


Figure 3-37. Gunner's Primary Sight Elevation Servo Assembly

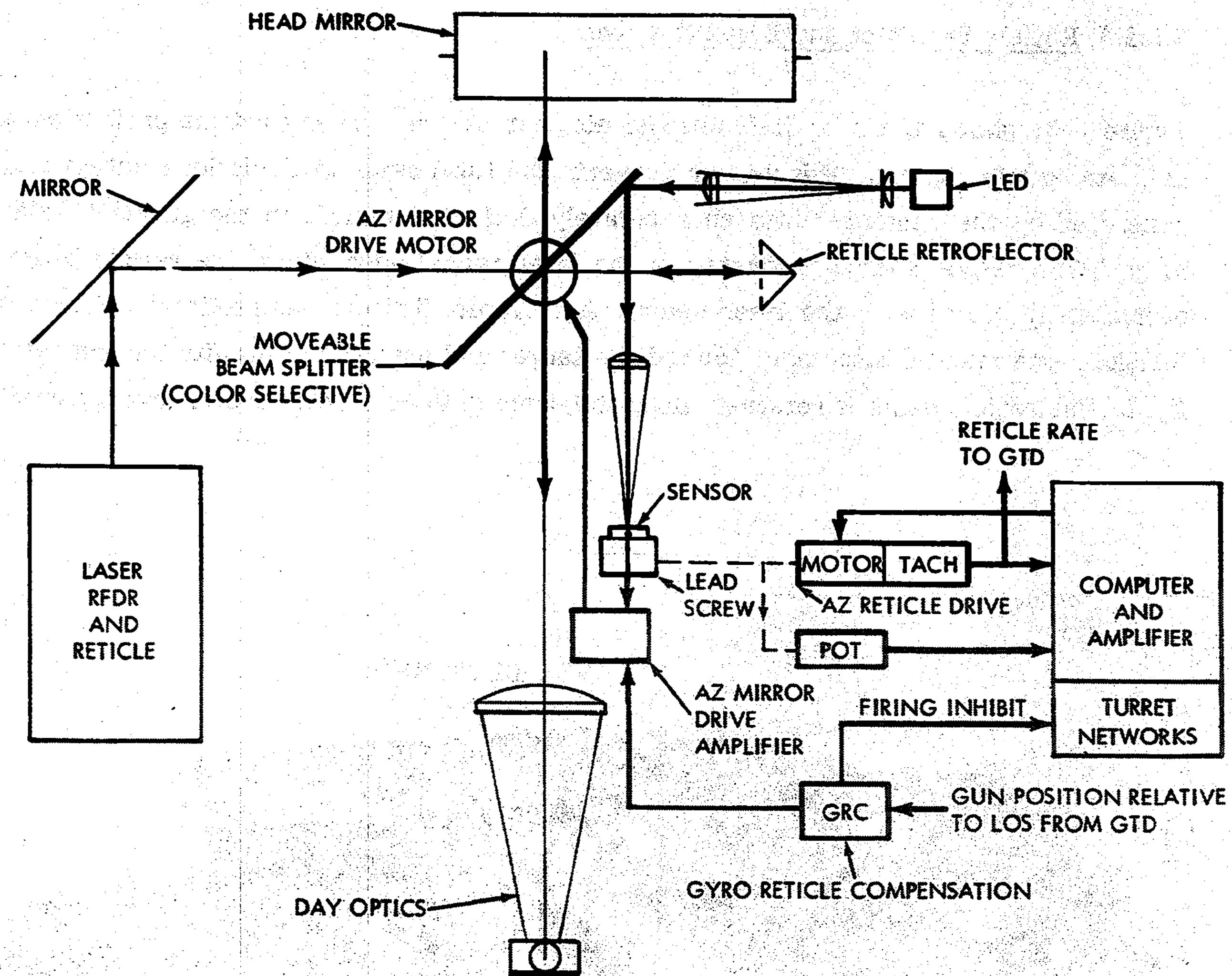


Figure 3-38. GPS Reticle Projection and Azimuth Control

reflected by the beamsplitter into the gunner's day optics. Since the gunner's line-of-sight also passes through the beamsplitter, the reticle is superimposed on the gunner's field of view.

The movable beamsplitter is controlled by two sequential servo-systems. The azimuth reticle-drive servo positions photosensors of the azimuth mirror-drive servo according to the computer-generated azimuth offset angle. The azimuth mirror-drive positions the beamsplitter according to the postion of the photosensors. The rate of the azimuth reticle drive is also supplied to the gun/turret drive system to counterrotate the turret in azimuth and maintain the reticle on the target when azimuth offset is applied.

The azimuth reticle-drive servo uses a potentiometer for position feedback and a tachometer for stability feedback. These feedback signals are converted to digital signals in the computer and summed with the total azimuth offset position. The resulting error signal is converted to analog, amplified, and applied to the azimuth reticle drive servomotor. The motor drives the carriage holding the photosensors for the azimuth mirror drive.

The azimuth mirror-drive servo uses an optical sensor for position feedback and a tachometer for stability feedback. Displacement of the dual-matched photosensors by the reticle-drive servo applies a differential error voltage to the servomotor driving the beamsplitter until the reflected beam of the light-emitting diode is centered on the photosensors. Total range of angular deflection possible for the reticle is ± 45 mils. A direct-drive torque motor and tachometer are used to obtain high accuracy and reliable performance.

Gyro Reticle Compensation (GRC) is applied to the azimuth mirror-drive to hold the reticle on the target when azimuth disturbance inputs beyond the bandwidth of the turret control system are encountered. The turret stabilization spatial position error is applied to the azimuth mirror-drive to counterrotate the reticle and maintain it on the target. The gun is inhibited from firing for azimuth errors greater than 0.30 mil.

3.5.2.4 Laser Rangefinder

The Laser Rangefinder (LRF) employed in the fire control system is a Neodymium Yttrium Aluminum Garnet (YAG) laser transmitter coupled with range receiver using a silicon-avalanche diode detector. The laser rangefinder shown in figure 3-39 is a separate bolt-on module to the gunner's sight. It is hermetically sealed as is the interface on the Gunners Primary Sight (GPS) thus allowing easy removal and replacement with the GPS installed in the tank. It is dry nitrogen purged and employs purge valves conveniently located for easy access purging within the tank without need of special tools. The LRF, once attached to the GPS, also serves as the GPS reticle projector. An outstanding feature of the LRF integration into the fire control system is the absence of any controls except the lasing button on the handles and an armed-safe, first-last return logic switch

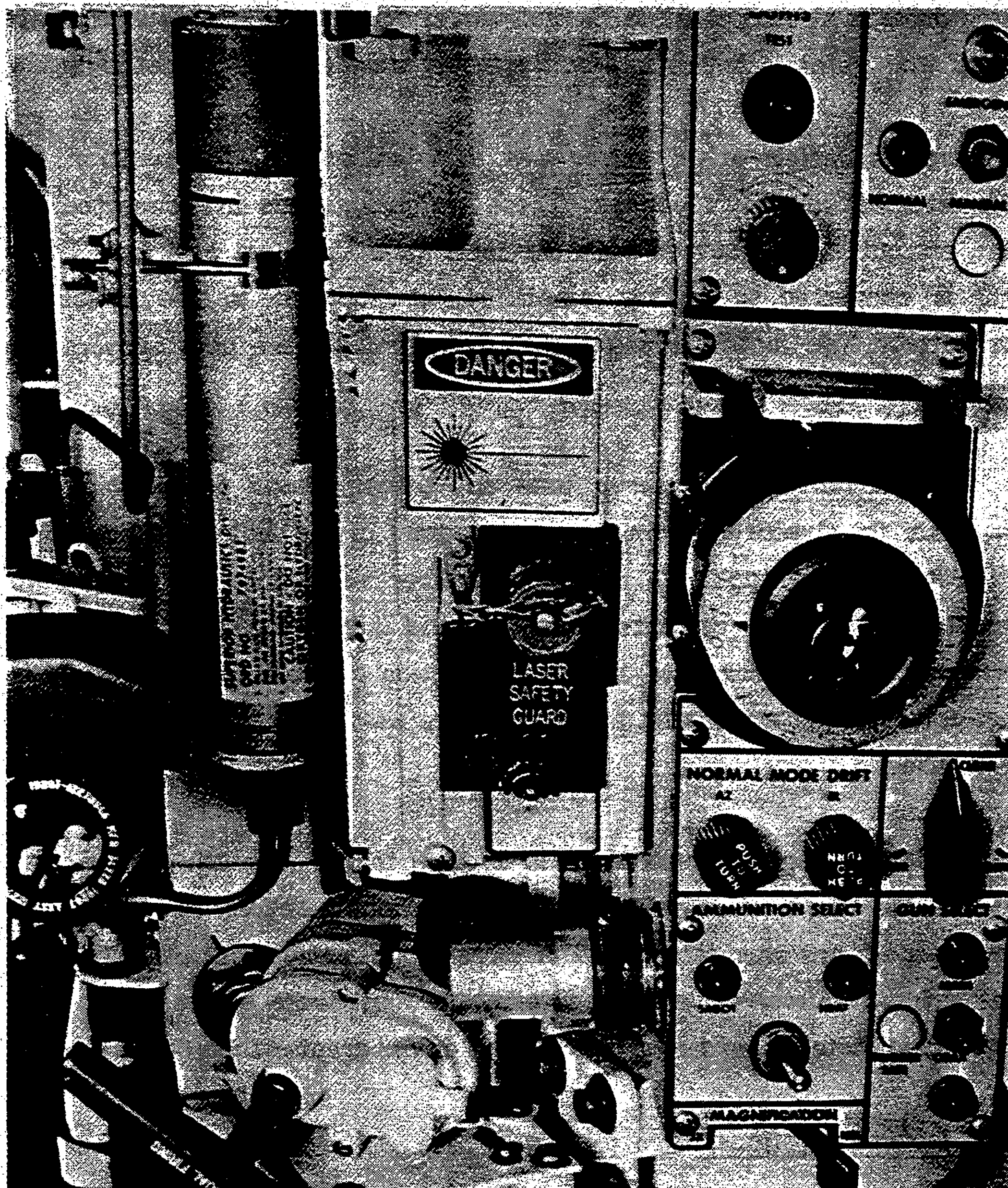


Figure 3-39. Laser Rangefinder

on the rangefinder. All range sensings are entered directly into the computer. A range readout is provided in both the commander's and gunner's field of view, along with a multiple-return indicator. The LRF makes use of last-return logic to implement successful ranging through fog, dust, and smoke. However, first-return logic is available for use in unusual tactical situations.

The last-return logic is achieved through the use of a dual counting chain. One counts continuously out to maximum range (7990m), and the other resets to zero for each return received. At the time the continuous counter reaches maximum range both counters stop and the time differential or range difference between counter-chains indicates "actual last return" range.

The rangefinder/computer interface consists of the range binary-coded decimal (BCD) lines, the range-ready signal, the continuous monitor signal, and the built-in test (BITE) command and response. When the laser "fire" signal is given, the laser emits a pulse and measures the time from laser fire to received-return and the LRF logic displays a range ready signal to the computer which then accepts the range displayed on the BCD lines. This range is stored by the computer until a subsequent ranging sequence is completed. The rangefinder also continuously provides a go or no-go signal to the system which indicates that both pulse forming network (PFN) and receiver detector bias are present and that counter, logic and power supplies are operational. In addition, as part of the gunner-commanded sequence test, upon receiving the test command from the computer, the LRF runs through its own internal test verifying that the counterchains are functioning, power supplies are up and within limits, and previous transmitted energy output was within limits. It then transmits a known range to the computer if the system is functional.

Should a LRF fault occur, the commander can enter "battle range" and enter any change to battle range by means of the toggle switch and the eyepiece range readout or the gunner can enter the estimated range similarly on the computer control panel.

3.5.2.5 GPS Controls and Displays

The GPS controls and indicators shown in figure 3-40 are functionally arranged on the face of the gunner's panel to facilitate their utilization by the gunner. The following is a listing of the controls and displays and a brief description of their functions:

RETICLE CONTROL PANEL

- o RETICLE intensity control rheostat: adjusts reticle brightness.

- o Defroster ON/OFF toggle switch: energizes the thermostatically controlled defroster and illuminates an indicator light (GREEN) when the defroster is on.

FIRE CONTROL PANEL

- Panel lights TEST pushbutton switch: illuminates all indicator lamps and displays when actuated.

- INDICATOR lamp intensity control rheostat: adjusts indicator lamp intensity on the GPS.

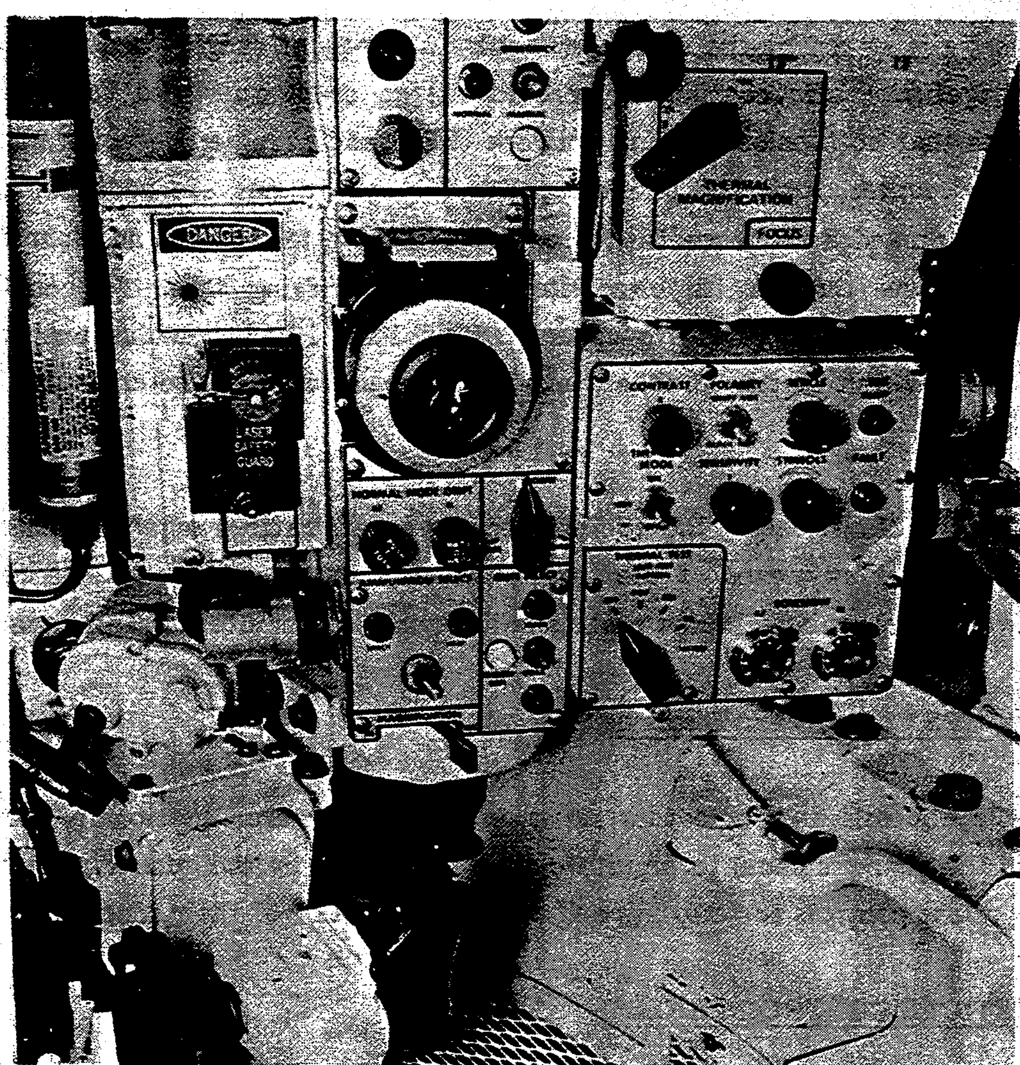


Figure 3-40. Gunner's Panel

- Fire control MODE toggle switch and indicator lamps: selects operating modes of fire control system: either "MANUAL", "NORMAL" or "EMERGENCY".

- Azimuth/Elevation NORMAL MODE DRIFT controls: potentiometers used to null out stabilization system drift.

- DIOPTER adjustment: rotary mechanical adjustment of eyepiece, used to bring scene and reticle images into sharp focus.

- FILTER/SHUTTER/CLEAR selector: rotary mechanical knob, positions a neutral density filter to reduce scene brightness, or a shutter to block out the day scene for thermal system operation, or a clear window for normal viewing conditions.

- Gun select MAIN/COAX/TRIGGER SAFE toggle switch and indicator lamps: switch selects gun (main or coax) or trigger safe (deactivates trigger circuits). Switch in coax position also selects coax ammunition. Indicator lamps display the selection that has been introduced into the control circuitry by the gunner. "Trigger safe" is always selected when turret power is first applied.

- AMMUNITION SELECT toggle switch and indicator lamps: switch selects main gun ammunition type and indicator lamps display the selection that has been introduced into the control circuitry by the gunner.

- MAGNIFICATION selector: lever control, selects either 3 or 10 power magnification.

- Laser first/last-return and safe switch: Located on the laser, selects first or last target range return or allows the gunner to inhibit the laser from accidental firing.

- Range and system status display - Range data and system status information (READY TO FIRE, MALFUNCTION, MULTIPLE LASER RETURN SYMBOLS) are displayed on the CRT tube in the thermal system and superimposed on the field of view in front of the eyepiece.

THERMAL IMAGING CONTROL PANEL

o MODE control:	off/standby/on, energizes system.
o POLARITY switch:	white hot/black hot, selects target contrast.
o SENSITIVITY control:	adjusts system receiver sensitivity
o CONTRAST control:	rheostat adjusts level of contrast
o Status indicator:	indicates operating temperature achieved and faults.
o THERMAL MAGNIFICATION selector:	mechanical module to select 3 power or 10 power magnification.
o FOCUS:	permits focusing from 50 meters to infinity.
o SYMBOLS:	adjusts the level of brightness of the range and system status display in the CRT.
o RETICLE:	adjust the level of brightness of the thermal scene reticle and polarity.

3.5.2.6 Gunner's Night/ Thermal System

Night vision is provided by a parallel-scan Thermal Imaging System (TIS) which senses heat radiation in the 8-14 micron range. The temperature distribution in the scene is displayed as a visible scene from a CRT which can be viewed through the GPS/CGPSE eyepiece. The system relies primarily on emitted rather than reflected radiation, and depicts the temperature profile of the scene. A dual-power option provides magnifications of 9.8 and 3 power with a rectangular field of view of 2.5 by 5.0 degrees and 8.0 by 15 degrees, respectively. The effective range of the TIS depends on the temperature contrast of the target and air but is the same for day or night operation. The functional elements that comprise the TIS when interfaced with the GPS elements are shown in figure 3-41 and the major components are shown in figure 3-42.

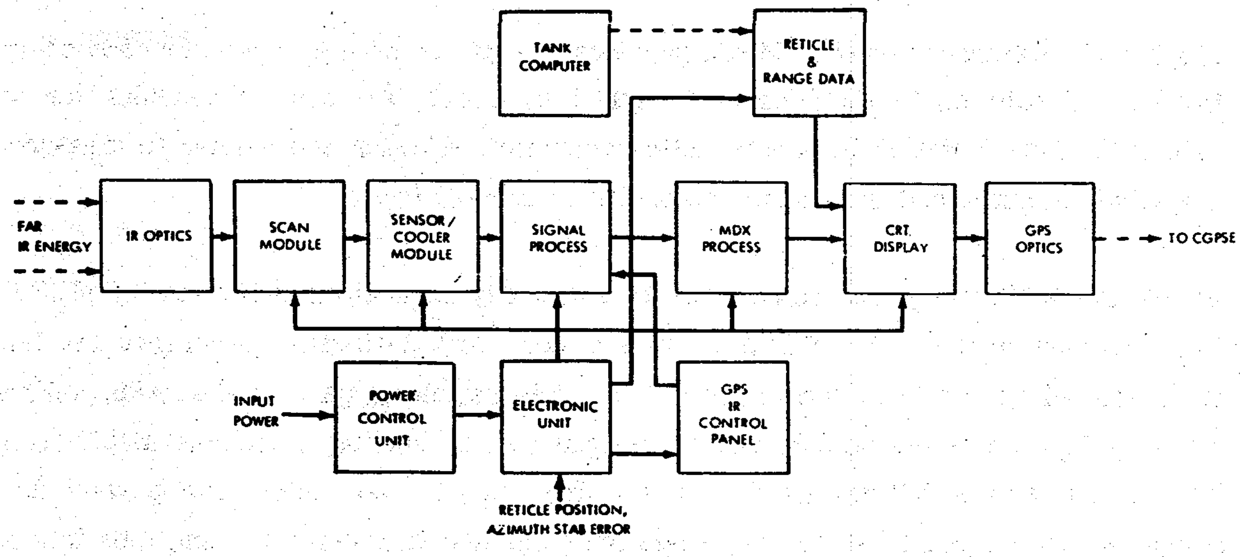


Figure 3-41. Thermal Imaging System Functional Diagram

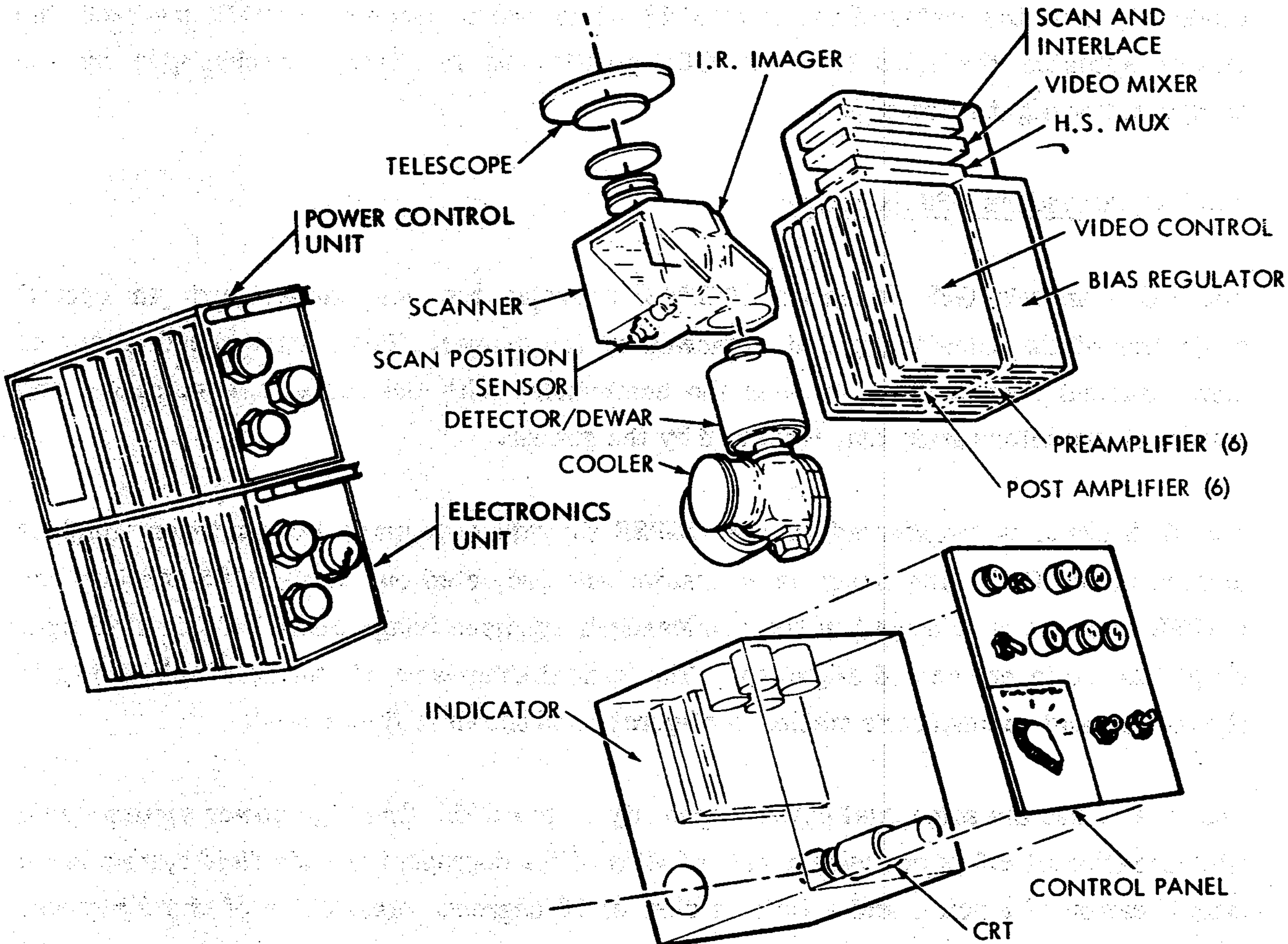


Figure 3-42. Thermal Imaging System Major Components

3.5.2.7 Muzzle Reference Sensor

The Muzzle Reference Sensor (MRS), provides the gunner with a means for correcting the fire control solution to compensate for gun tube bend. The system provides for semi-automatic data insertion in the ballistics computer, allowing the gunner to measure the magnitude of gun tube bend and the computer to correct for it.

To use the MRS, the gunner selects the 10 power day channel and actuates the MRS lever to IN position on the GPS. This procedure introduces a deflection prism into the line of sight and brings the MRS reticle into view. The reticle is part of the MRS collimator assembly located at the muzzle end of the gun tube. For night use, the MRS reticle is illuminated with a tritium light source. The gunner then opens and powers up the computer control panel, he then depresses the palm switch to place the gun tube in a level position and uses the boresight toggle switch to superimpose the fire control reticle red aiming dot over the center of the black MRS reticle cross. When accurately centered, the gunner actuates the MRS lever to OUT position on the GPS, thereby updating the computer boresight reference.

3.5.3 Commander's GPS Extension

The Commander's GPS Extension (CGPSE) provides the commander with an optical projection of the same scene that is viewed by the gunner. This scene, including day or night thermal scenes, also provides the commander with the same reticle, range, and system status information that is viewed by the gunner.

The GPS scene is transferred to the CGPSE through a common beamsplitter which is located in the GPS. The image is collimated and projected out of the GPS and into the CGPSE where it is reimaged in the commander's eyepiece image plane. Collimated light simplifies the interface and alignment. The optical schematic of the CGPSE is shown in figure 3-43 and commander's station configuration is shown in figure 3-44.

The CGPSE has the same dual power capability as the GPS. The high power system has a magnification of 9.5 power with a field of view of 6.2 degrees; the wide field system has a magnification of 3 power and a field of view of 16 degrees. Resolution of the 9.5 power system is 40 cycles/mil for high contrast targets and 25 cycles/mil for low contrast (20 percent) targets. The exit pupil diameter is 6mm and clear eye distance is 22mm, which

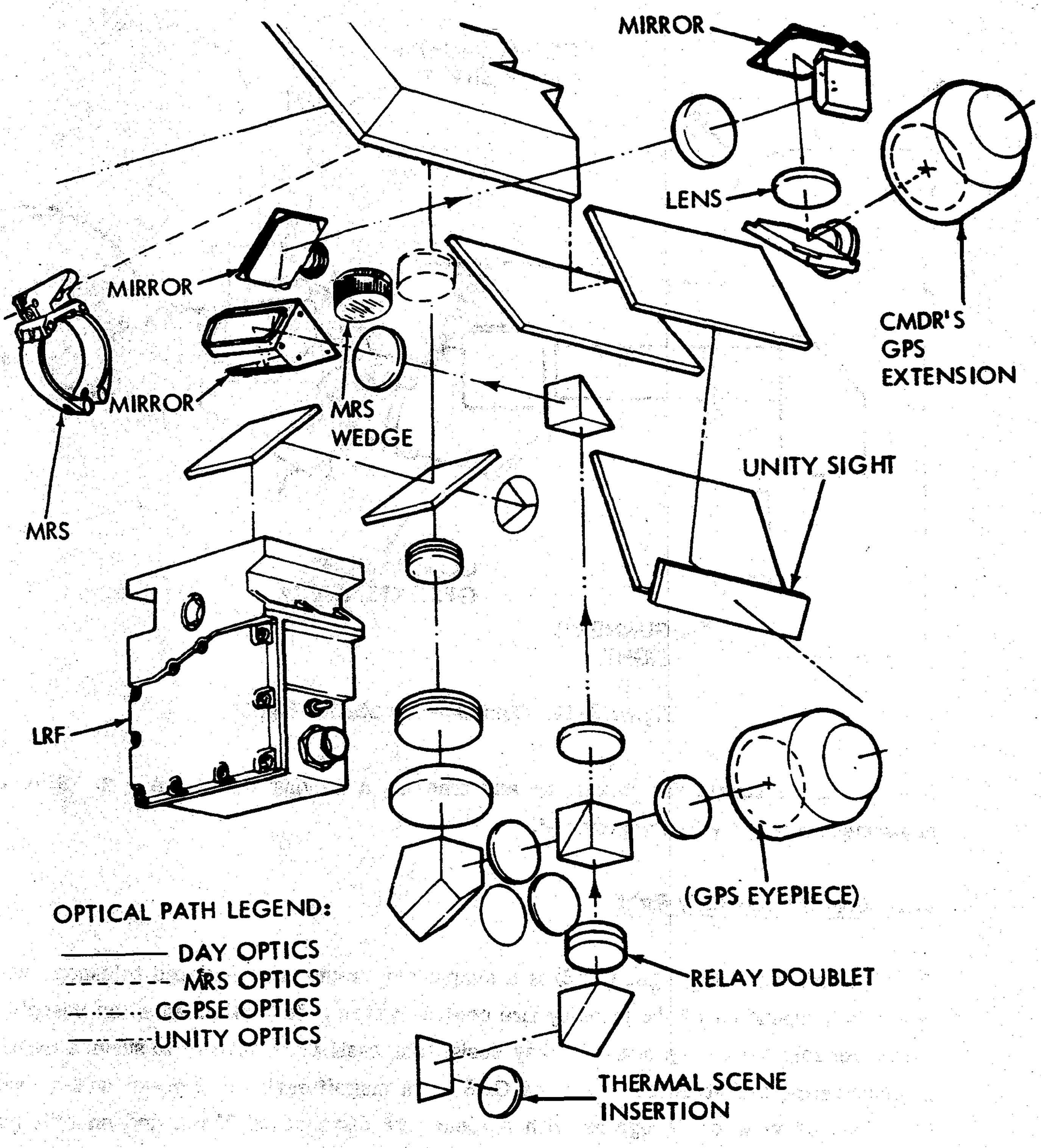


Figure 3-43. GPS Optical Schematic

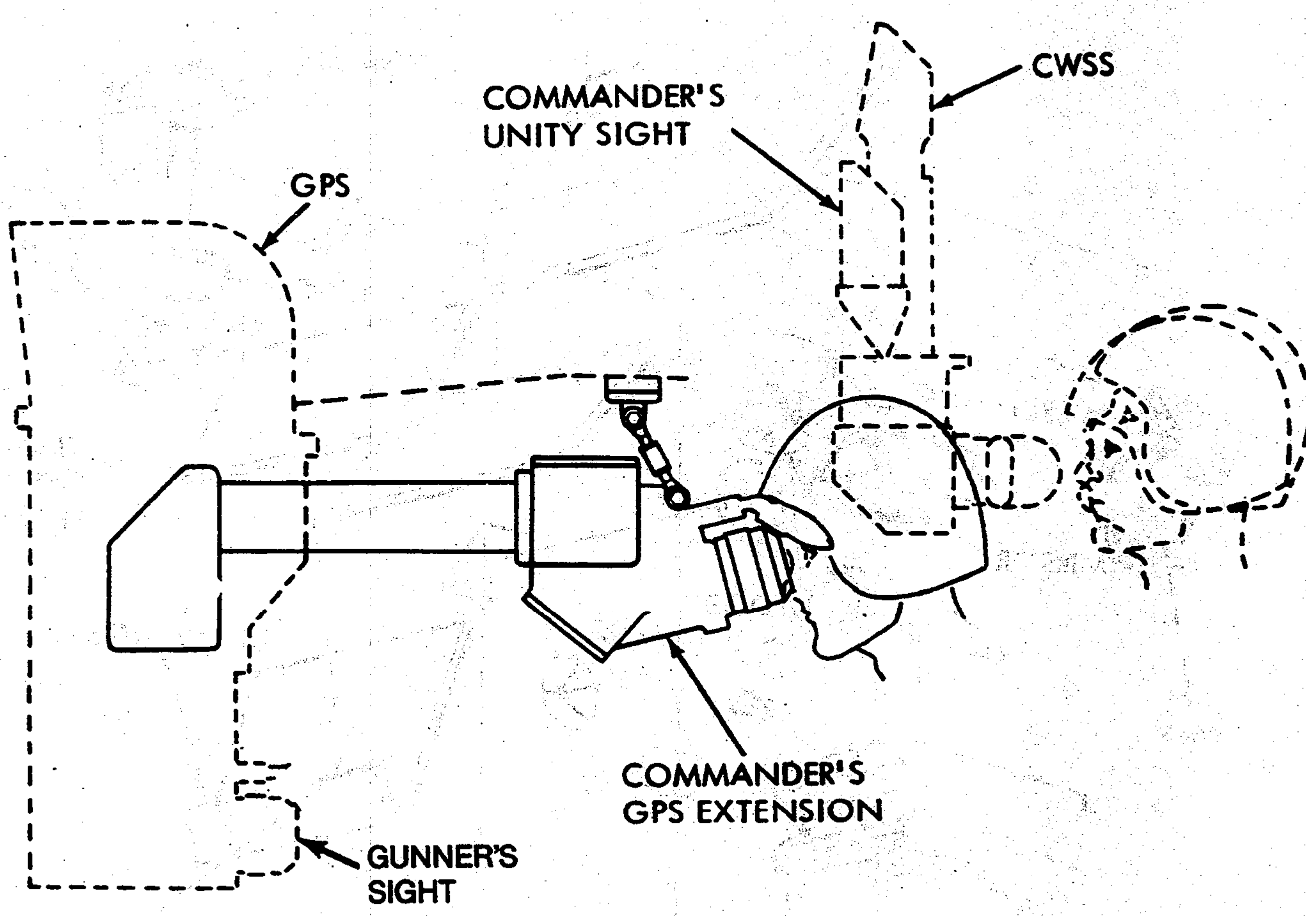


Figure 3-44. Commander's Station Sights

is more than adequate for picking up and tracking a moving target. A + 2, -6 diopter adjustment capability is also provided.

3.5.4 Gunner's Auxiliary Sight

The Gunner's Auxiliary Sight (GAS) is a simple gun mounted articulated telescope which operates independent of the primary fire control system. It is intended as an unsophisticated, reliable backup system with key design emphasis on capability to survive multiple nonpenetrating ballistics impacts. The GAS has a magnification of 8 power which results in a field of view of 8 degrees with a clear eye distance of 25mm and an exit pupil diameter of 6mm. A + 2, -6 diopter adjustment capability is also provided. The resolution of the GAS is 25 cycles/mil, which is sufficient to engage targets out to the maximum effective range of the ammunition. A 50 db attenuation of 1.06 micron laser light is provided for gunner's eye protection along with a neutral density filter for reducing scene brightness. The GAS provides ballistics reticles for SABOT and HEAT ammunitions.

The GAS shown in figure 3-45 is mounted coaxially with main gun. It utilizes an articulating joint to reduce eyepiece movement when the main gun is elevated or depressed. With the eyepiece hanger and the rotary articulating joint, image rotation is minimized at the extremes of travel (24° CW at 20° ELEV and 24° CCW at 10° DEPR). In the area of greatest usage, between 10° ELEV and 5° DEPR, the image rotation is approximately 10° CW and 15° CCW, respectively. Two separate focal plane ballistics reticles are provided (SABOT and HEAT). Selection of the reticles is accomplished by the reticle select lever. Reticle illumination is provided by light emitting diodes. The GAS has been designed for optimization of the aperture through the frontal armor. The entrance pupil is located at a point 25 inches forward of the front optical element.

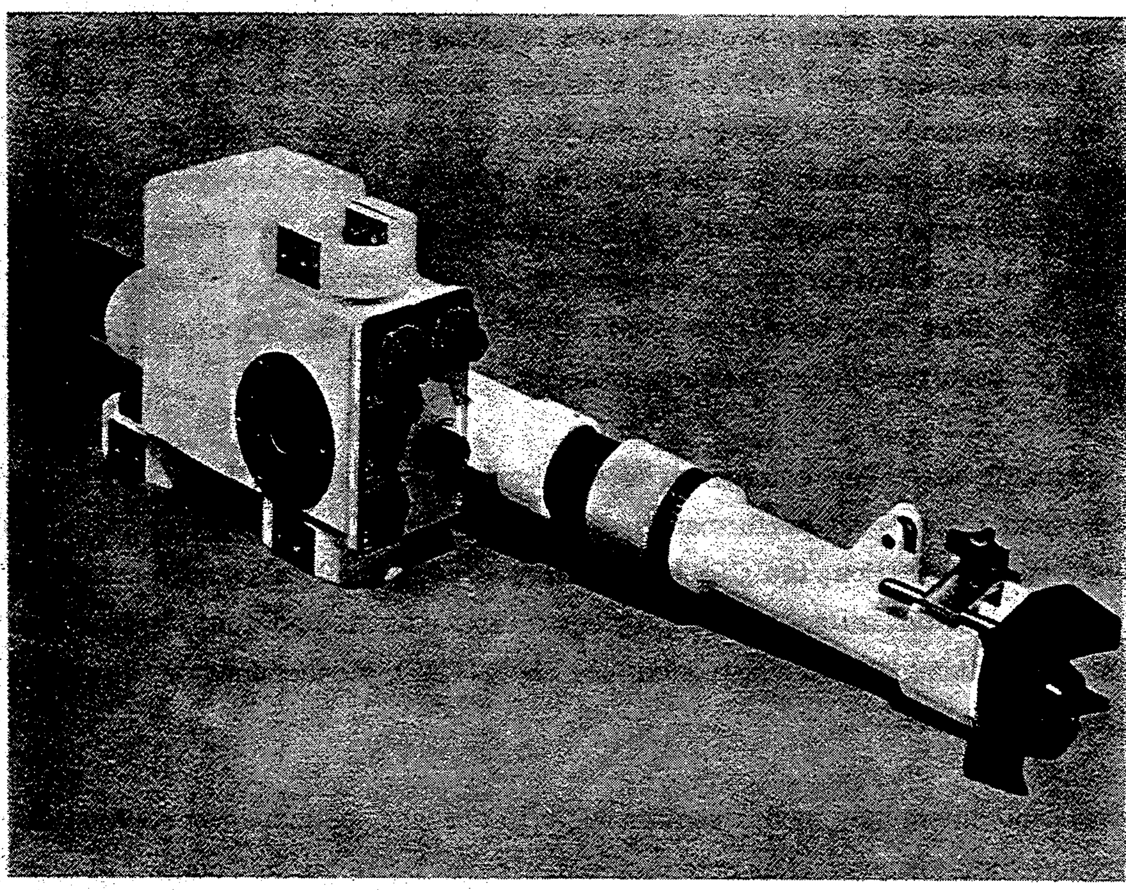


Figure 3-45. Gunner's Auxiliary Sight

3.5.5 Gun/Turret Drive

The Gun/Turret Drive (G/TD) and Stabilization System provides control of the main and coaxial weapons in the stabilized (normal), non-stabilized (emergency), and manual modes of operation. The stabilized (normal) mode is the mode of operation which is used normally for all gun and turret control functions. The non-stabilized (emergency) mode provides backup powered operation independent of stabilization system sensors and circuits. The manual system provides gun and turret control, independent of the vehicle electrical and hydraulic power sources.

In the normal mode of operation, the gun is electrically slaved with the stabilized head-mirror in the GPS and the turret is stabilized in azimuth. This approach, in conjunction with the gyro reticle compensation described in paragraph 3.5.2.3 provides the target acquisition and retention capabilities necessary for both moving and stationary vehicle operations. Infinitely variable and continuous tracking capability from 0.25 to 75 mils per second in azimuth and from 0.25 to 25 mils per second in elevation is provided to the gunner and commander. At least 750 mils per second of slew capability from control handle commands is provided for the turret in azimuth. An elevation handle command slew rate of 400 mils per second and a 750 mils per second rate for azimuth and elevation in response to stabilization system commands is also provided. Stabilization system commands for these rate levels are required to maintain aim retention during vehicle mobility over rough terrain or evasive maneuvers.

The electrically controlled emergency mode provides a highly reliable powered backup mode for handle command performance approaching that of the normal mode. During emergency mode operation, the GPS head mirror is electrically slaved to the gun. With azimuth and elevation control provided directly to the turret and gun, sighting may also be performed utilizing the Gunner's Auxiliary Sight (GAS), independent of the operational capabilities of the GPS.

The normal and emergency modes contain logic to prevent the gun from striking the rear deck of the vehicle at gun angles below zero degrees. In the normal mode full control is provided to the GPS head mirror to allow target tracking below zero degrees even though the gun may be elevated to clear the rear deck. Firing is inhibited during this condition until the gun automatically returns to its proper alignment (the head mirror position plus any elevation ballistics correction offset) when the turret or gun moves out of the interference zone. In the normal and emergency modes hydraulic power is normally supplied by an engine driven pump. For "engine off" conditions hydraulic power is supplied for operation in these modes by an electric motor driven auxiliary hydraulic pump which enables the G/TD system to provide frequent full handle command slew capabilities in azimuth or elevation and sustained target tracking capabilities of 30 mils/sec in azimuth or 16 mils/sec in elevation.

The manual controls design concept utilizes a direct gear drive for azimuth control and a hydraulic fluid handpump for elevation control.

3.5.5.1 Elevation Axis

Mechanical stops in the gun mount limit the gun travel in the elevation axis to 20 degrees elevation and 10 degrees depression with respect to a horizontal turret plane. A hydraulic cylinder is used to drive the gun in either direction and/or to hold the gun in the proper position. Figure 3-46 depicts a functional-block diagram of the elevation axis control system.

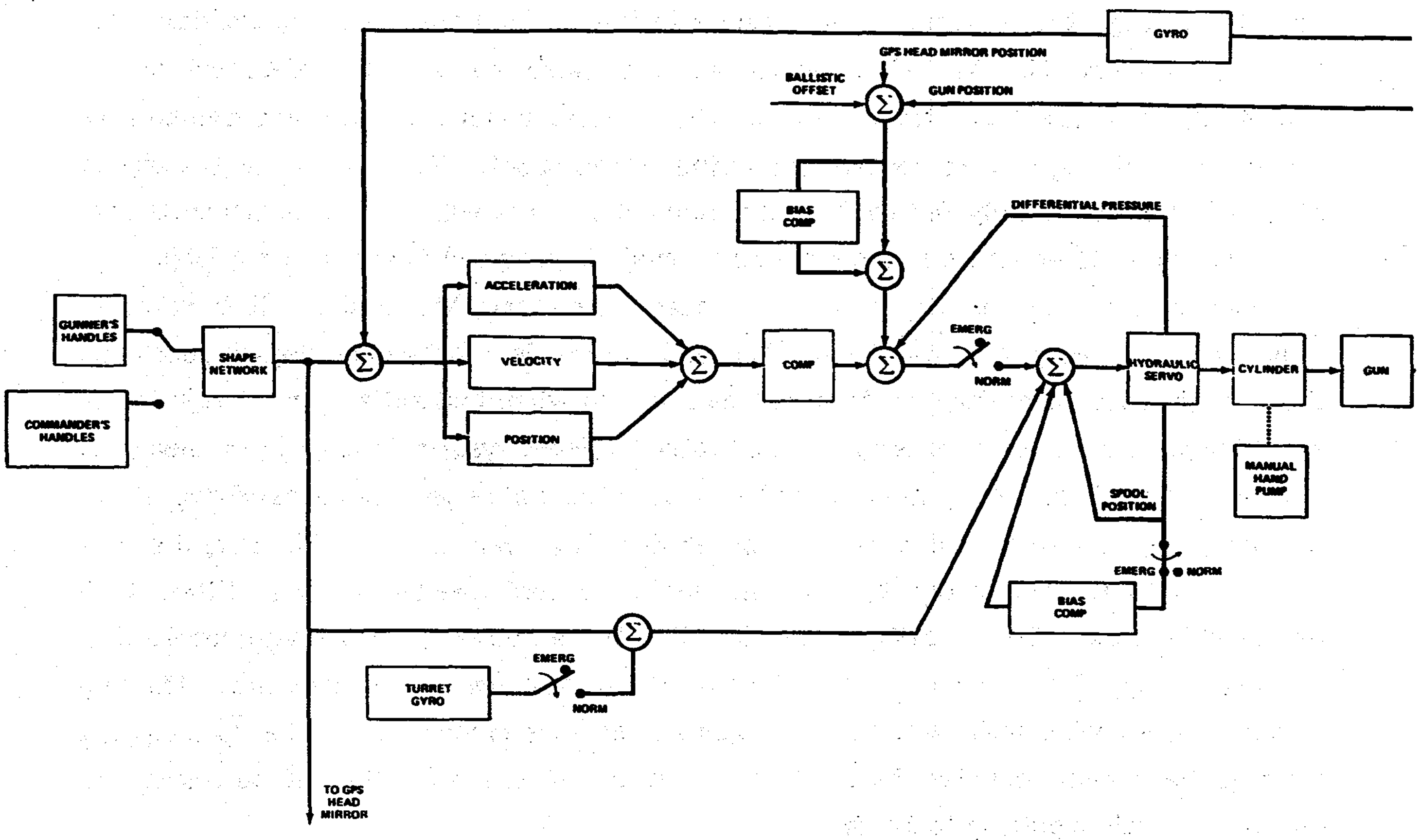


Figure 3-46. G/TD Elevation Axis Functional Block Diagram

In the normal mode, handle commands and sensor feedback signals are processed in the G/TD electronics to provide rate commands to the elevation cylinder under moving and stationary vehicle conditions. The control system is of the proportional type, incorporating integral and differential control compensation. Velocity lag error is minimized by using an open loop pitch rate input generated by the turret gyro. During cross-country operations, turret pitch rate is sensed by the turret gyro and used to rotate the gun at an equal and opposite rate to provide a stable gun position. Any inaccuracies of this open-loop drive signal cause a spatial position error to be developed. This error is sensed by the gun gyro and the gun sight resolver network, which both provide drive signals to eliminate the error. Differential pressure feedback (torque feedback) is used to provide additional system damping. Feedback compensation is provided to eliminate positional errors resulting from hydromechanical component wear, environmental changes and tolerance variations. Handle commands from the gunner or commander are shaped and summed with the feedback signals logic to provide smooth tracking capability.

In the emergency mode, handle commands are processed through the handle signal shaping network to directly control the hydraulic servomechanism. Manual control is also provided through the servomechanism from a hydraulic fluid handpump, accumulator and lock valve system. Manual mode provides 10 mils in elevation per handcrank revolution at a peak effort of less than eleven pounds. The servomechanism contains a hydraulic flow amplifier consisting of a servovalve and output stage spool. The position of the output stage spool is electrically fed back to the input of the servovalve. Bias compensation to eliminate rate offset errors in the emergency mode is provided in this control loop. The servomechanism also contains a pilot operated, four port, two position lock valve to minimize drift during system off conditions and to provide a 0.1 second engagement time delay to prevent uncommanded transient gun motion when hydraulic power is applied to the drive system. Internal crossover relief valves prevent system damage in the event an external object is struck by the gun, and a manual lock valve prevents backdriving of the manual handpump when the elevating mechanism is power driven. Oil cleanliness is maintained to the servovalve by the self contained replaceable hydraulic filters with bypass indicators. The elevating mechanism is attached directly to the servomechanism for low entrapped oil volume. This, in conjunction with the nine square inch effective piston area, a double shear zero backlash gun attachment mechanism, and a dual support strut gimbal mount provides the stiff drive system necessary for the gun to respond to elevation terrain inputs up to 10 Hz.

3.5.5.2 Azimuth Axis

The azimuth gearbox assembly provides control of the turret throughout 360 degrees of travel in the normal, emergency, and manual modes of operation. Figure 3-47 is a functional block diagram of the azimuth axis. As in the elevation axis, handle and stabilization sensor commands are processed in the normal mode through a proportional controller incorporating integral and differential control compensation. Yaw rate is sensed to counter rotate the turret to maintain a spatial position reference. Errors in this

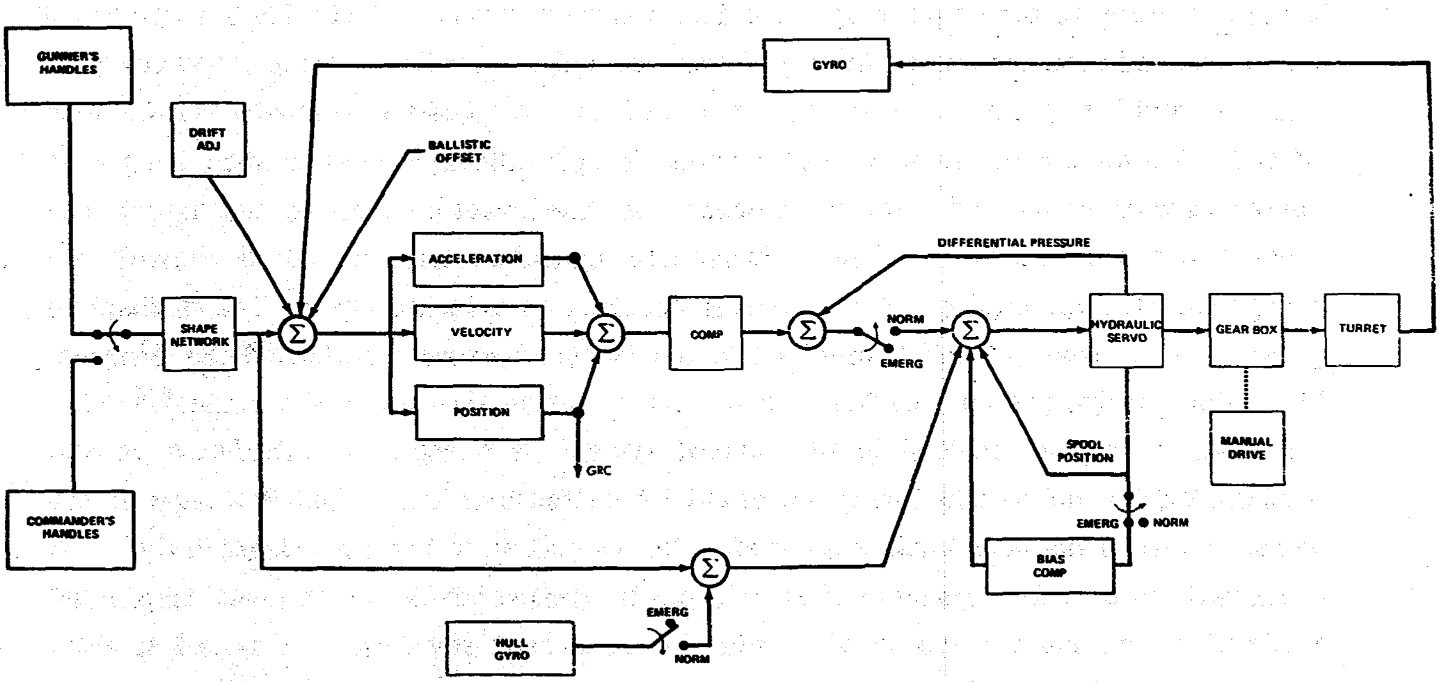


Figure 3-47. G/TD Azimuth Axis Functional Block Diagram

counter rotation are sensed by the azimuth portion of the dual axis gyro mounted on the GPS head mirror drive and a command signal is generated that is processed to eliminate the error. Differential pressure feedback is used for increased damping. This approach is effective in stabilizing the turret for input disturbances of frequencies up to approximately 4 Hz. Uncompensated errors in this range, as well as input disturbances of up to 60 Hz, are processed through the derived position channel and the Gyro Reticle Compensation circuit to reposition the reticle to maintain target alignment. This essentially stabilizes the reticle and provides the advantages obtained with the stabilized azimuth sight method without the disadvantages of a two axis sight stabilized system.

Handle commands from the gunner or commander are processed in the normal and emergency modes in a similar manner to the elevation axis. Bias compensation is provided by the velocity channel in the normal mode and by the servomechanism output spool position feedback in the emergency mode.

The azimuth servomechanism houses a servovalve, flow amplifier, engage transient time delay, a strain gage type differential pressure transducer, replaceable hydraulic filters with bypass indicators, a pilot operated crossover relief valve for motor bypass, and keep full anticavitators. A bent axis axial piston 0.95 cu. in. per rev. hydraulic motor is coupled directly to the output stage of azimuth servomechanism to provide low entrapped oil volume and establish a high stiffness hydromechanical coupling. The gearbox design is stiffened and incorporates a single split output pinion. The gearbox assembly, with a ratio of 640:1, houses the turret brake/clutch which is hydraulically released when the power controls are energized and is spring actuated when the power controls are not in use. The brake/clutch prevents turret slippage during hull maneuvers with the power controls de-energized, but allow slippage if the turret is struck by an external object. The mechanical ground for the brake/clutch is provided in the manual traverse section of the gearbox. The detent design prevents backdriving of turret motion through to the manual handle. Additional safety is provided in the manual system by a separate slip clutch on the handcrank drive and by a hydraulic power cut-off switch that is actuated by a lever on the handcrank when the handcrank is grasped. The manual drive has two speeds/ratios. A 640:1 ratio to provide a response of 10 mils per handcrank revolution on level terrain and a 1280:1 to provide a response of 5 mils per handcrank revolution on sloped terrain. Because of the low friction of the manual drive, and in particular of the hull/turret race assembly which is itself less than 200 pound-feet, the manual traverse peak effort is less than 14 pounds on level ground.

3.5.5.3 Handles and Controls

The control components used in the gun/turret drive (G/TD) system are the gunner's and commander's handles, the gyros, and the electronic control unit. The gunner's and commander's handles provide identical control capabilities for the operator, including palm, trigger, and laser switches. The application of hydraulic power to the control system is provided by energizing one of the system palm switches, which in turn applies power to actuate the turret power valve. On the gunner's dual handles, either the left or right or both palm switches must be squeezed in order to move the GPS head mirror and gun or turret, to lase, or fire the main or coaxial weapon. Interlocking the palm switches in this manner prevents inadvertent bumping of the control handles causing undesired results. The palm switch on the commander's single grip joy stick type control handle provides the same function as for the gunner, as well as initiating the override capability for taking control of the main or coaxial weapon. Except for the grip and grip attaching mechanism, both the commander's and gunner's handles assemblies are identical. Linear variable differential transformers (LVDT's) are cam driven through ±90 degrees in azimuth and bell crank driven through ±30 degrees in elevation to provide an output voltage proportional to handle position. The mechanisms are self centered with spring forces selected to provide smooth and easy operation. The handle grips are shaped to comfortably fit the hand for easy accomplishment of the required functions and to minimize operator fatigue.

Three identical rate gyros are used specifically for the G/TD system to sense gun rate in elevation, vehicle pitch rate, and hull yaw rate. Turret rate is sensed by the azimuth output of the dual axis gyro which is located in the gunner's primary sight.

The modularized electronics unit provides the analog processing logic needed to control the elevation and azimuth axis, and the power supply and regulator circuits for the G/TD system. The elevation and azimuth control logic is individually contained on two separate printed circuit boards for ease of troubleshooting at upper echelon maintenance. The power supply components, except heat sink mounted power transistors, are contained on a single printed circuit board. The electronics unit has a test connector on the front face that provides connections to measure pertinent operational conditions throughout the G/TD system.

3.5.6 Ballistics Computer System

The Ballistics Computer (BC) System calculates and provides command signals representing ballistic, lead, and parallax offsets for the GPS reticle projector (azimuth) and the main gun elevation. These offsets are dependent upon vehicle environment, static cant, target slant range, tracking rates, ammunition type, and operational modes. In addition, to zeroing values for nine main gun and two coaxial weapon round types, the GPS to main gun azimuth and elevation alignment values are selectively summed to the computed ballistics offsets. The system consists of the ballistics computer which includes the electronics unit and the control panel, the cant sensor, the crosswind sensor, and other vehicle components/systems which provide computer inputs. Figure 3-48 depicts the functional relationships between the system components and other vehicle systems/components.

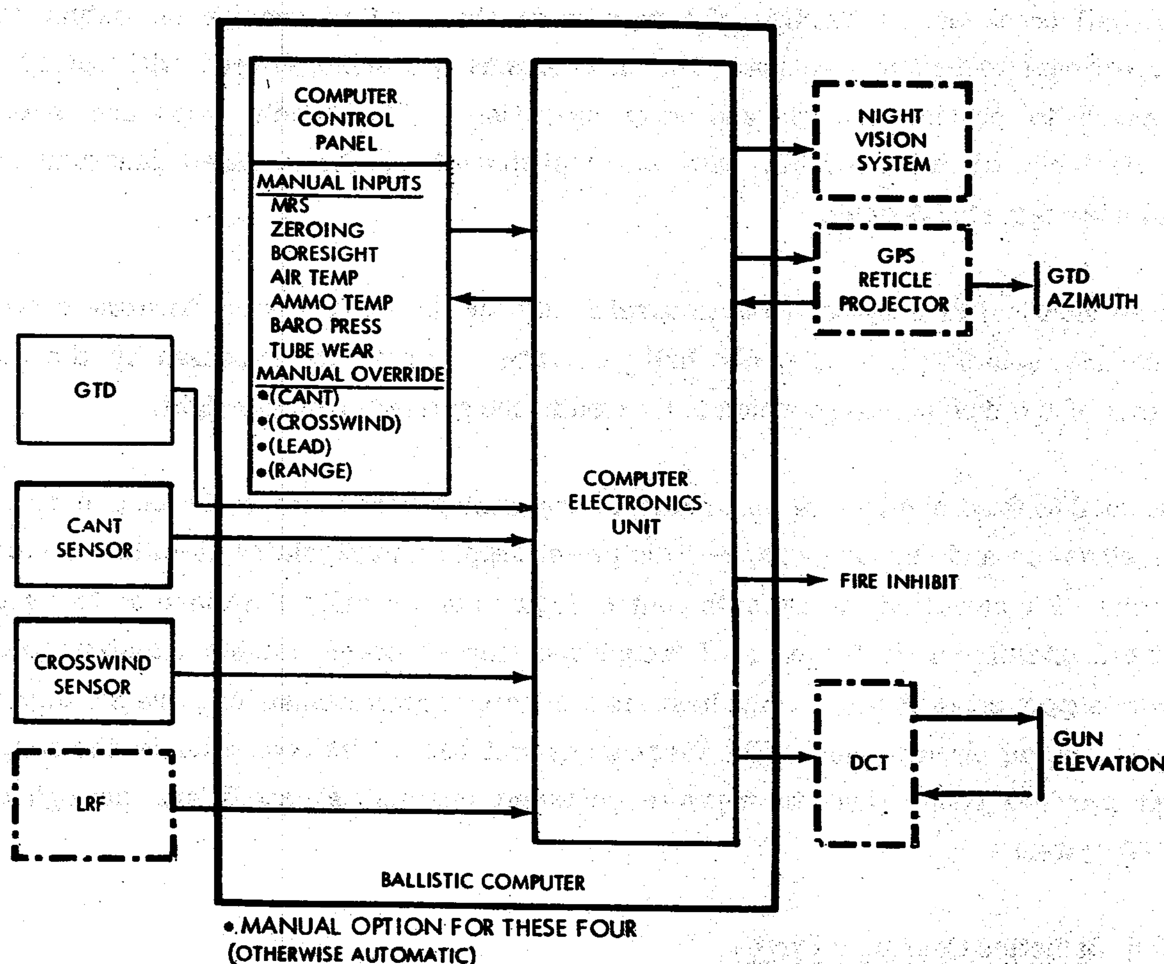


Figure 3-48. Ballistics Computer System Functional Block Diagram

The BC automatically receives signals of the vehicle's cant angle, the crosswind velocity, the range, and the tracking rate (for lead corrections). These signals are combined with the manual inputs such as zeroing, boresight, MRS, air temperature, ammo temperature, and barometric pressure to calculate the required offsets. Electronic signals representing these offsets are automatically fed to the appropriate drive system (azimuth GPS reticle drive or elevation gun drive).

Continuous, automatic malfunction detection capability is incorporated in the fire control system to identify to the commander if and when a gross malfunction has occurred in the ballistics computer system and other major components. A manually initiated built in test sequence actively exercises the ballistics computer, cant sensor, crosswind sensor, laser rangefinder, G/TD system, LOS stabilization system, data link, and the GPS reticle drive and compares their individual responses to a predetermined pass/fail criteria. Failure sources are identified by a number code on the computer control panel for appropriate repairs. Manual override capability for the automatic inputs of cant angle, crosswind velocity, lead rate, and range is provided for emergency operation.

3.5.6.1 Ballistics Computer Components

Ballistics Computer (BC) components shown in figure 3-49 include an Electronics Unit (EU), a Computer Control Panel (CCP), a digital computer, a power supply, and interface circuitry. The CCP contains all of the controls and displays required to provide manual inputs to the computer.

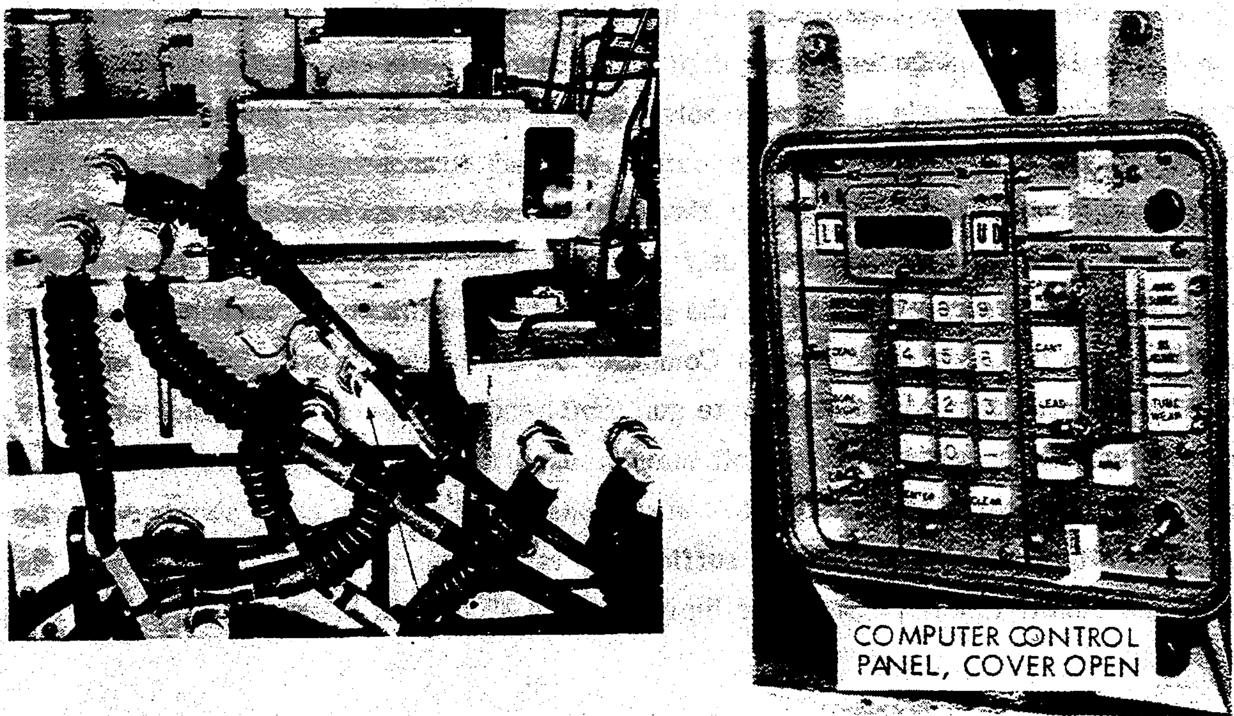


Figure 3-49. Ballistics Computer EU and CCP

The digital computer contains 16,384 words of solid state eraseable programmable read-only memory (EPROM). The operating program and ballistics coefficients for eleven types of rounds are included in this permanent storage area. Two main rounds and one coax round are immediately selectable via the gunner's ammo and weapon select control, while the remainder are useable by means of a manual entry of a sub-type via the computer control panel. Other changes, such as new ammo, can be accomplished by re-programming one computer board. A "scratch pad" memory is used to store panel inputs. Required power for this memory is supplied by the vehicle battery when the computer is installed in the tank. When vehicle battery power is lost an internal battery provides power to maintain the memory. This battery is a low voltage rechargeable unit mounted in the computer electronics. When vehicle installed, a charging circuit within the BC will maintain the battery capacity for longer than 5 years. An inadvertent loss of both BC internal battery power and tank battery power would only require reentry of the manual data using the control panel. Conversion from English system manual entry units to metric can be accomplished by removing an internal jumper wire.

The digital control transformer (DCT), located in the LOS Electronics Unit, and other interface circuitry are organized onto individually removable circuit cards. The DCT is the interface element between the digital computer and the analog gun elevation servo. The signal from the gun trunnion resolver is applied to the DCT, the required ballistics offset is added, and the resultant output is used to appropriately position the gun elevation. In azimuth the computer, through a closed loop servo, positions the reticle for the proper offset, while simultaneously the turret system senses that reticle motion and counterdrives to correctly position the gun/turret. The Muzzle Reference Sensor (MRS) correction is used by the Ballistics Computer to automatically provide the appropriate boresight corrections to accommodate gun tube bending. Special circuits are provided in both elevation and azimuth to inhibit main weapon firing until the sight to gun pointing error is within pre-established limits. In stationary and average cross country operations, the associated control systems are sufficiently responsive to minimize any firing delays from the inhibit function (the error limits are $\pm$ 0.20 mils in elevation and $\pm$ 0.30 mils in azimuth).

The Computer Control Panel (CCP), shown in figure 3-50, is normally closed during combat operations. It provides the capability to manually enter ballistics parameters and alignments and to override the automatic sensors in the Ballistics Computer System. The

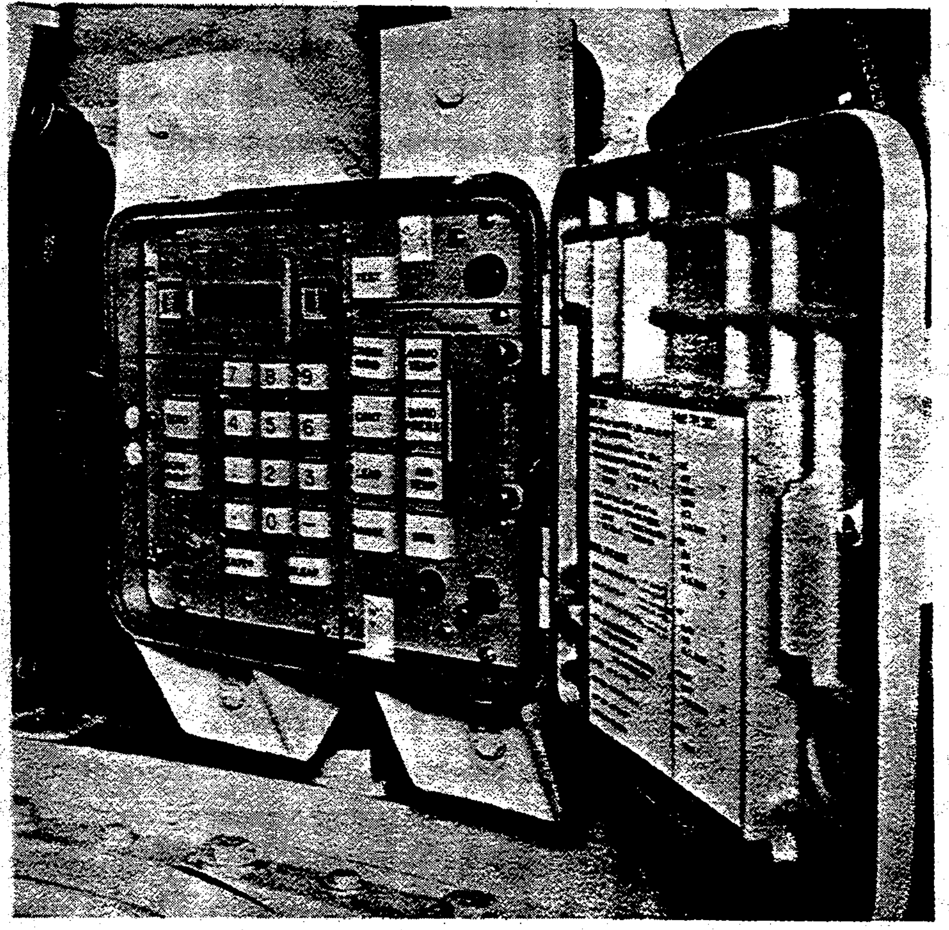


Figure 3-50. Computer Control Panel

control panel is divided into four major sections: a manual input section, automatic input self test section, boresight/zero section, and a keyboard/display section.

The manual input section contains provisions to enter conditions of air temperature, barometric pressure, ammo temperature, battlesight, and ammo sub-type select. Any of these manual inputs may be used by depressing the appropriately labeled key. The computer will acknowledge the addressing of the particular item by illuminating the key that was pressed and by displaying the value currently stored in the computer memory for that item. The units associated with the display are those in common use (e.g., degrees Fahrenheit for temperature) and are listed for convenience on instructions affixed to the control panel cover. After pushing the labeled key, to change the value of the manual input, press the appropriate numerical entries on the keyboard.

These entries are immediately visible in the numeric display. If the new value appears correct then the enter key is depressed, the manual input lamp that was illuminated goes out, and the new value is stored for use in the ballistics solution equations. Should a totally erroneous entry be made (e.g., 6,000 degrees air temperature) the computer will not accept the input and the associated manual input key will flash indicating that another input is to be made. It is impossible for any incorrect entry to damage or upset the fire control system. Air temperature and pressure are input from data provided locally to the crew. Ammunition temperature is observed from a thermometer dial located to the commander's right which is measured from a turret bustle mounted sensor and manually entered in the computer. Special provisions are made to enter a separate battle range for each ammo sub-type and to select a secondary level ammo sub-type, e.g., a particular type of SABOT ammunition.

The fire control system self test is initiated by pressing the test key on the control panel while engaging the gunner's or commander's palm switch. As long as this switch is pressed, all the lights on the panel are illuminated for lamp check. Release of the switch automatically sequences tests of fire control subsystem. Should a failure occur, the no-go lamp illuminates, the sensor lamp involved illuminates and a numeric code is displayed to identify the failure source. Code information is contained on the panel cover. At the completion of a successful test, "PASS" will appear in the display. The automatic inputs to the computer, crosswind, cant, lead, and range can be addressed in the same manner as the manual inputs. Depressing one of these keys causes the lamp to illuminate and the particular sensor is ignored by the computer. The value of the sensor output may be changed manually. Fixed entries can then be made in the same manner as for manual inputs. This capability allows the fire control system to properly function in a slightly degraded mode in the event of a sensor failure.

Boresighting and zeroing of the GPS in day, night, and MRS modes to the main gun is accomplished by using controls on the GPS and the CCP. These modes are set up automatically with selection of "gun", "ammo type", "day", "night", or "MRS". To boresight the GPS, the reticle is moved by use of the up/down/left/right toggle on the computer control panel until it coincides with the aiming point of the gun tube. When a satisfactory lay is obtained, the solution for the sight is entered by depressing the enter button. Zeroing is accomplished in a similar manner, after depressing the zero button, by toggling the GPS reticle to the center of impact of the zeroing rounds fired for the particular ammunition selected and pushing the enter button.

3.5.6.2 Cant Sensor

The cant sensor is a simple and rugged pendulous device located on the tank ceiling above the gunner. The ballistics computer contains automatic logic to ignore the cant input when the vehicle is moving. The pendulum is magnetically dampened and a rugged potentiometer is utilized to measure pendulum position. Figure 3-51 depicts the cant sensor.

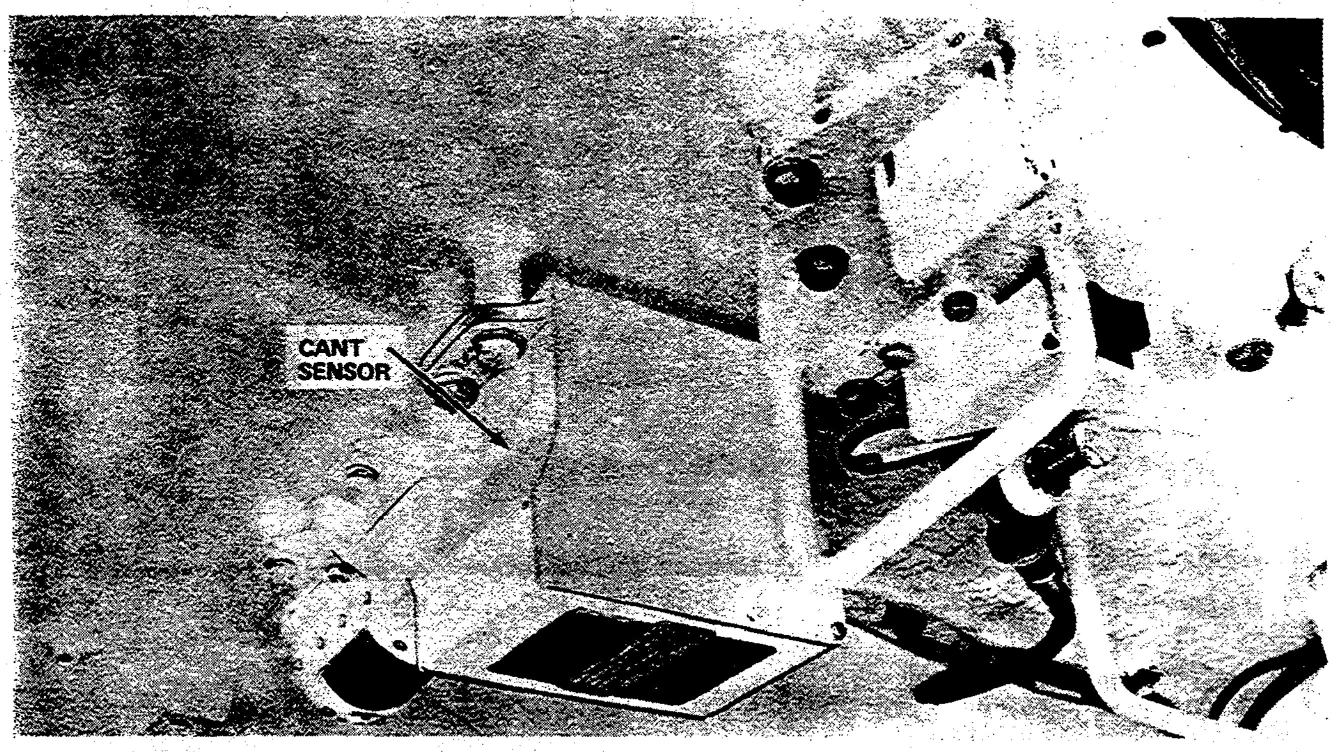


Figure 3-51. Cant Sensor

3.5.6.3 Crosswind Sensor

Mounted at the center top rear of the turret bustle, the sensor measures the crosswind component of the wind at the vehicle. The sensor is shown in figure 3-52. This rugged unit and a special rubber shock mount allow flexure to the horizontal plane upon impact with obstacles such as tree limbs. This flexure prevents damage or permanent orientation shifts to the wind sensor.

The crosswind sensor significantly improves moving vehicle hit performance by measuring any lateral vehicle motion perpendicular to the line-of-sight to the target. This

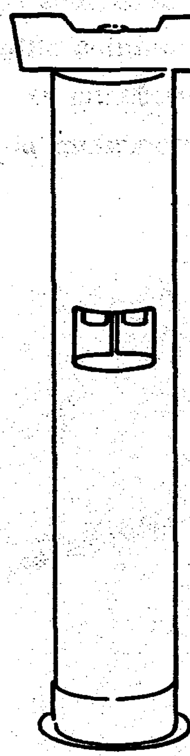


Figure 3-52. Crosswind Sensor

information is used by the computer to provide trajectory corrections to compensate for the effect of that motion.

The crosswind sensor also provides continuous self testing of its power supply voltages and analog output stage circuits. Any failures are automatically indicated to the commander by the illumination of the fire control no-go indicator in the sights and on the control panel. In the manual self test sequence, a simulated wind signal is inserted and the calibration of the wind sensor electronics is verified.

3.5.7 Turret Controls

The turret control system has been thoroughly integrated and standardized to require as few panels and controls as practical. The commander's vehicle master power switch, in parallel with another switch at the driver's station, is provided in the turret for added convenience and safety. The gunner and commander are provided a separate, independently adjustable control for varying indicator lamp intensities. In addition, each crew position, and an additional position above the coax machinegun, has a separate adjustable dome lamp to control light levels for convenience and security.

3.5.7.1 Emergency Firing Components

Emergency aiming and firing of the main gun is possible. A power switch is located on the gunner's auxiliary sight control panel. When the switch is energized, power is supplied to the GAS to illuminate the reticle for night use. Azimuth and elevation positioning of the main gun and the commander's weapon is achieved by the manual controls provided. The main gun can be manually fired by utilizing the blasting machine conveniently located above the gunner's control handles and below the Gunner's Primary Sight.

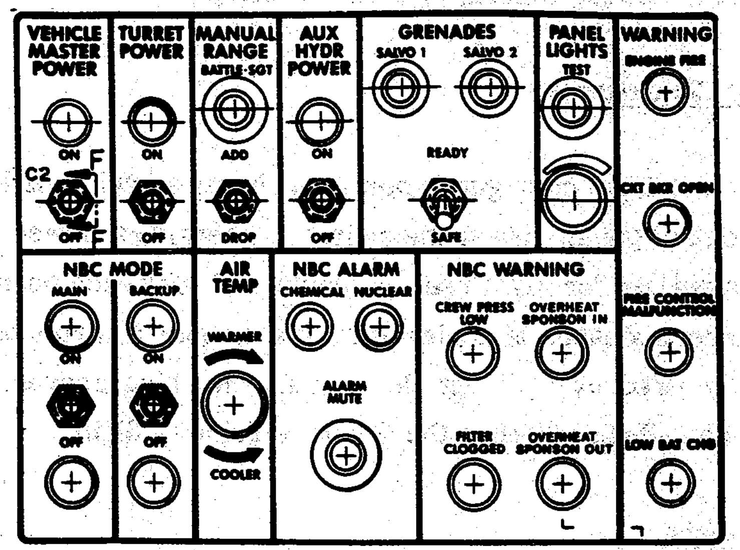
3.5.7.2 Turret Control Panels

Turret controls are provided for the commander, gunner, and loader. The commander's and loader's controls are contained in individual control panels while the gunner's controls are integrated into the Gunner's Primary Sight. An indicator lamp test control on the commander's panel illuminates all lamps and displays when actuated.

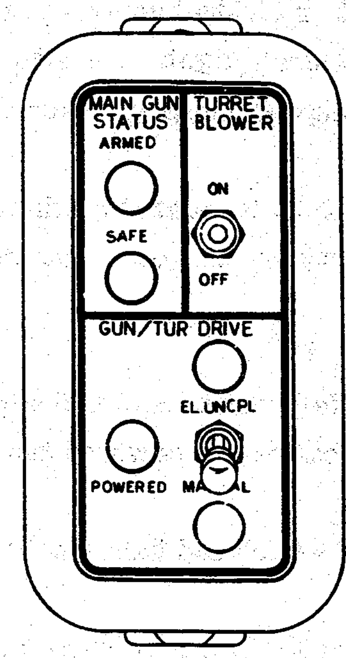
The Loader's Panel shown in figure 3-53 is located on the left turret wall by the loader's station. The panel is optimized for use by the loader and contains the following switches and indicators:

- "GUN/TURRET DRIVE" safety switch and indicator lamps: Lever locked toggle switch which activates or deactivates powered gun and turret movement.
- "TURRET BLOWER" on/off switch and indicator lamp.
- "MAIN GUN STATUS" indicator lamps: Display the status of the main gun firing circuit either "armed" or "safe".

The Tank Commander's Panel (TCP) shown in figure 3-53 is located on the right turret wall, adjacent to the commander's station. It contains controls to operate the turret, the NBC system, and the Commander's Weapon Station (CWS). The panel contains the following controls and indicators:



TANK COMMANDER'S PANEL



LOADER'S PANEL

Figure 3-53. Turret Control Panels

- o "VEHICLE MASTER POWER" (VMP) switch and indicator lamp: The Driver's Master Panel (DMP) switch and this switch at the commander's station controls vehicle power from either crew station.

- o "TURRET POWER" switch and indicator lamp: Controls the turret power. Circuitry automatically resets to "off" with loss of Vehicle Master Power (VMP).

- o "MANUAL RANGE" switch: Battle sight push-button inserts the preset range value for the selected ammunition type. The add/drop switch adjusts the battle sight input manually.

- o "AUXILIARY HYDRAULIC POWER" switch and indicator lamp. Controls auxiliary hydraulic power. Hydraulic power is "on" when VMP is "on", with the engine "off" or with the engine "on" and the main hydraulic pump failed.

- o Smoke "GRENADES" switches: Safety switch arms/safes grenade firing circuit. Salvo 1 push button switch fires 3 grenades from the left and right grenade launcher. Salvo 2 push button fires the remaining grenades.

- o "PANEL LIGHTS" test and intensity control: Pushbutton allows verification that all lamps are working. Control knob provides control of the lamp intensity.

- o Warning indicator lamps:

  - oo ENGINE FIRE: Flashes, indicating fire in engine compartment. Duplicate to lamp on Driver's Instrument Panel.

  - oo LOW BATTERY CHARGE: Indicates low battery state of charge.

  - oo CIRCUIT BREAKER OPEN: Indicates tripped circuit breaker in the turret.

  - oo FIRE CONTROL MALFUNCTION: Indicates a malfunction within the fire control system or disconnected connectors.

- o "NBC MODE MAIN" switch: Controls the main NBC system. Circuitry automatically comes on 10 seconds after engine start and automatically shuts off after engine shut off.

- "NBC MODE BACK-UP" switch: Controls the air recirculation blower system. Can be shut off by either the NBC MAIN ON switch or the BACK-UP OFF switch.

- "AIR TEMP" control: Knob allows variation of air temperature of the NBC MAIN system.

- "NBC ALARM" mute: Push button cancels out the NBC alarm initiated by a chemical or nuclear detector signal.

- "NBC ALARM" indicator lamps:

  - CHEMICAL: Turns ON when chemical detector senses contamination above acceptable level; turns OFF when contamination concentration drops below danger level of chemical detector.

  - NUCLEAR: Turns ON when nuclear detector senses contamination above acceptable level; turns OFF when contamination concentration drops below danger level of nuclear detector.

- "NBC WARNING" indicator lamps:

  - CREW PRESS LOW: Indicates the pressure in the turret is too low to sufficiently protect crew in NBC environment; should shut off when NBC main is ON and hatches closed.

  - OVER HEAT SPONSON IN: Indicates air temperature of NBC system into sponson is too high and could damage system.

  - FILTER CLOGGED: Indicates the NBC filters are clogged by sensing the pressure drop across the filters.

  - OVER HEAT SPONSON OUT: Indicates temperature of air going into NBC filters is too high and will consequently damage filters.

3.6 ARMAMENT

3.6.1 General Descriptions and Function

The 120mm, M256 gun shown in figure 3-54 is semi-automatic, dropblock breech, counter recoil actuated and has an electrically operated firing device. The gun consists of a gun tube, evacuator chamber group, breech operating group, breech ring group, and breechblock group.

The gun tube is a one piece steel forging, cold worked, with a smooth bore for a 120mm round. The gun tube is attached to the breech ring by interrupted buttress threads and locked with a tapered stud, providing a quick change feature which permits removal and installation of the gun tube through the gun shield of the tank. This feature permits the combination gun mount, breech operating group, breechring group, and breechblock group to remain as a unit. A smooth surface immediately forward of the interrupted buttress threads provides the bearing surface for the gun tube in the recoil mechanism of the combination gun mount.

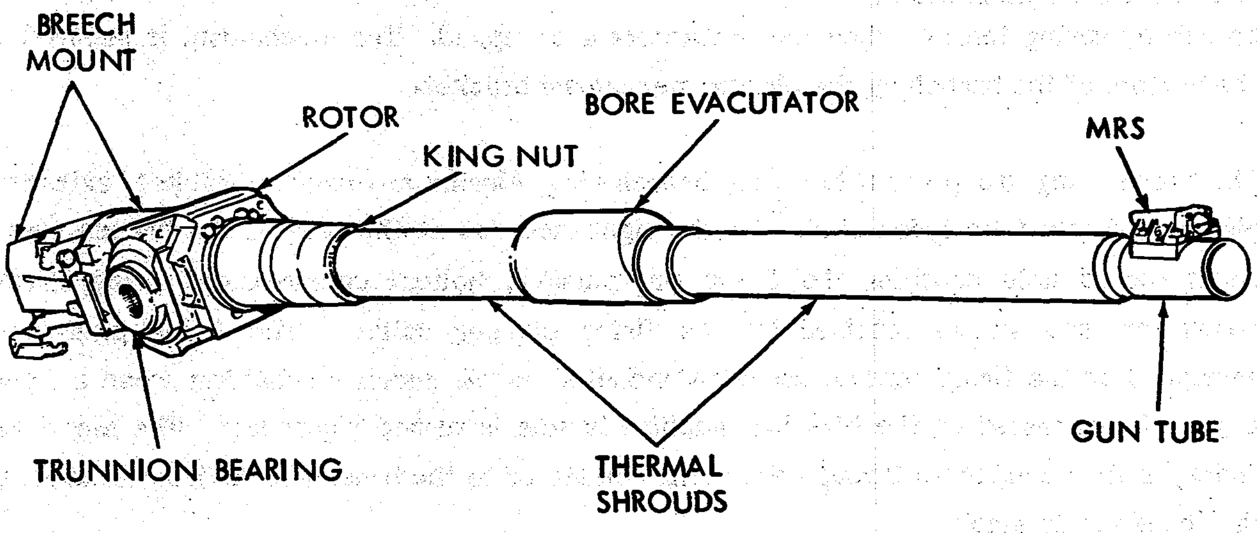


Figure 3-54. 120mm, M256 Main Gun and Mount

The evacuator chamber group aids in removing spent propellant gases from the tube preventing the escape of these gases into the crew compartment. The annular chamfers at the front and rear accommodate O-rings to eliminate leakage of the spent gases. The breech operating group actuates the breechblock to open and close the breech and move the extractors to eject the spent cartridge cases.

Operating crank handle - The operating crank handle which is separate from the gun, actuates the closing mechanism operating shaft and is used to manually open the breech.

Operating crank - The operating crank, which is pinned to the closing mechanism, is a shaft that has a crank arm and lug extension. The lug on the arm extension is beveled to push the breech operating cam outward. It then contacts the cam surface during counter recoil to automatically open the breech.

Breechblock crank - The breechblock crank, located on the center of the closing mechanism, is a curved lever that has a projecting, enlarged, hub with a half round, half square bore on the lower end, and a hole on the upper end. The rear surface of the upper end is notched to receive the tip of the breechblock group retractor drive which forces the retractor guide and retractor rearward to withdraw the firing pin assembly into the breechblock when the breech is opened.

Breech-closing mechanism - The breech closing mechanism automatically closes the breech by spring tension when the extractors are tripped. The mechanism is secured to the bottom of the breech by the closing mechanism bracket.

The breech-ring group consists of the breech-ring, closing mechanism bracket, extractor pivots, and gun tube index stud. On the right side and at the rear of the breech ring a counterbored hole contains the firing pin plunger, helical compression spring, firing conductor, and sleeve retained by the firing plunger collar. The firing plunger is energized by the firing contact assembly mounted on the recoil mechanism when a firing trigger is depressed or the blasting machine handle is turned vigorously. The electrical energy is then conducted through the firing conductor to the breechblock firing contact to the firing pin assembly.

The breechblock group is of the dropblock, sliding wedge design, that slides in grooved bearing surfaces in the breech-ring opening to open or close the breech. The breechblock group consists of the firing pin assembly with related parts and breechblock. Machined cam grooves (extractor paths), located on the forward portion of both sides of the breech block actuate the trunnions of the extractors mounted on pivot pins projecting inward from the left and right sides of the breech ring. Flat surfaces (trunnion seats) are provided at the end of each path for locking the breech block in the open position. When the trunnions of the extractors are positioned on the trunnion seats of the breech block, the breech block cannot be closed until the extractors are tripped. The electric firing pin assembly with firing pin spring is secured by a retainer assembly at the center of the breech block rear. The contact, that conducts electrical energy to the firing pin, is housed in a hole, perpendicular to the firing pin, in the right side of the breech block. The retractor driver, which is actuated by the breech block operating crank as the breech opens, forces the retractor guide and retractor rearward, withdrawing the firing pin assembly into the breech block. The breech block has a concave surface at the top for ease of loading a round. A tapped hole in the center of the concave surface is used for inserting an eyebolt to facilitate breech block removal. The upper portion of the front face is beveled to provide the wedging action needed to properly seat the cartridges in the breech ring body as the breech block is being closed.

3.6.1.1 Main Gun (120mm, M256) Characteristics

Weight of gun (complete)	4,192 lbs
Weight of gun tube	2,592 lbs
Weight of breech mechanism	1,506 lbs
Weight of evacuator (with locking nut)	45 lbs
Type	Tank gun, smooth bore
Breech	Sliding wedge, drop block counter recoil opening torque spring closing
Firing mechanism	Electric firing, automatic, mechanically retracted firing pin

Caliber	120mm (4.724 in.)
Length of gun assembly (complete muzzle to rear face breech)	5625mm (221.46 in.)
Length of tube	5300mm (208.66 in.)
Center of gravity of tube	1705mm (67.126 in.) from muzzle end
Center of gravity of complete gun (with bore evacuator)	1400mm (55.118 in.) from rear face of breech
Operation of firing mechanism	
Vehicle power	Gunner's and commander's control handle firing switch (depression actuated)
Emergency power	Blasting machine (mechanically operated)
Gun tube life	.020 in. Bore enlargement

3.6.1.2 Combination Gun Mount

The combination gun mount is a concentric recoil, hydrospring, constant-distance type that houses the 120mm gun. The combination gun mount supports the 120mm gun on trunnion bearings installed on pins set in the turret. Elevation and depression of the 120mm, M256 gun is accomplished by operation of a hydraulic elevating mechanism. The 120mm, M256 gun mount provides mounting surfaces for the coax machinegun, the gunner's telescope, and the auxiliary firing mechanism.

Combination Gun Mount Characteristics.

Concentric Recoil Mechanism

Type	Concentric hydrospring, constant recoil distance
Length of recoil (nominal)	12 in.
Length of recoil (maximum)	12.25 in.
Oil capacity of recoil mechanism and replenisher	8.2 gallons

Weight

Complete installation	7307 lbs
Combination mount (without rotor and shield, gunner's guard and assembly)	1690 lbs
Shield	700 lbs
Rotor	725 lbs

3.6.1.3 Main Gun Ammunition

The main gun ammunition is combustible cased and has a stub base. The base weighs approximately 10 pounds and is automatically ejected from the breech during gun recoil cycle. Basic main gun ammunition types are listed below and described in subsequent paragraphs.

AMMUNITION	TARGET
APFSDS (Armor piercing, fin, stabilized, discarding sabot, tracer)	Armored targets
HEAT (High explosive antitank)	Armored targets, antitank guns

3.6.1.3.1 Armor Piercing Fin Stabilized Discarding Sabot Round (APFSDS-T)

There are two types of armor piercing ammunition that will be used in the 120mm cannon as follows:

1. The 120mm APFSDS-T, M827 cartridge is a standardized kinetic energy, ammo defeating round which delivers a fin stabilized 38mm staballoy penetrator.

2. The 120mm APFSDS-T, M829 cartridge is a kinetic energy, armor deflecting round with an optimum penetrator (high L/D).

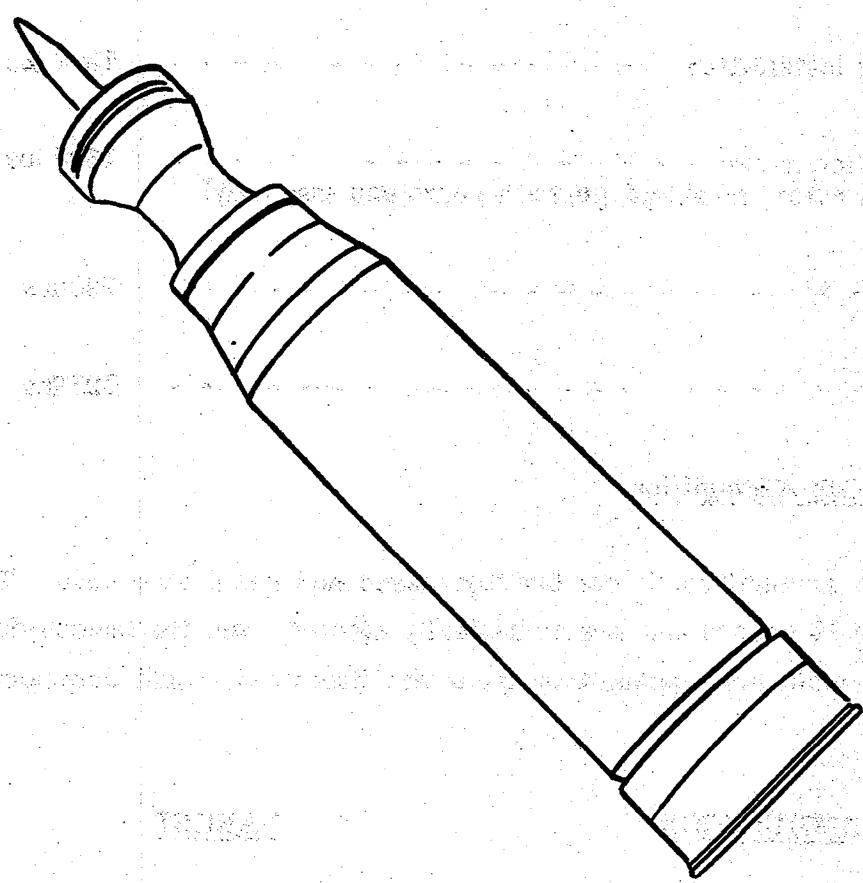


Figure 3-55. Armor Piercing Fin Stabilized Discarding Sabot Round (APFSDS-T)

3.6.1.3.2 High Explosive Antitank Round (HEAT-T)

There are two types of high explosive ammunition that will be used in the 120mm cannon as follows:

1. The 120mm HEAT-TP-T, M831 is a standardized target practice round for multipurpose use. It is a fin stabilized round using the same stick propellant system as is used with the MP-T round.

2. The 120mm HEAT-MP-T, M830 cartridge is a fin stabilized multi-purpose round. It is a standardized system using a steel case with a rubber obturator at the stub case mouth.

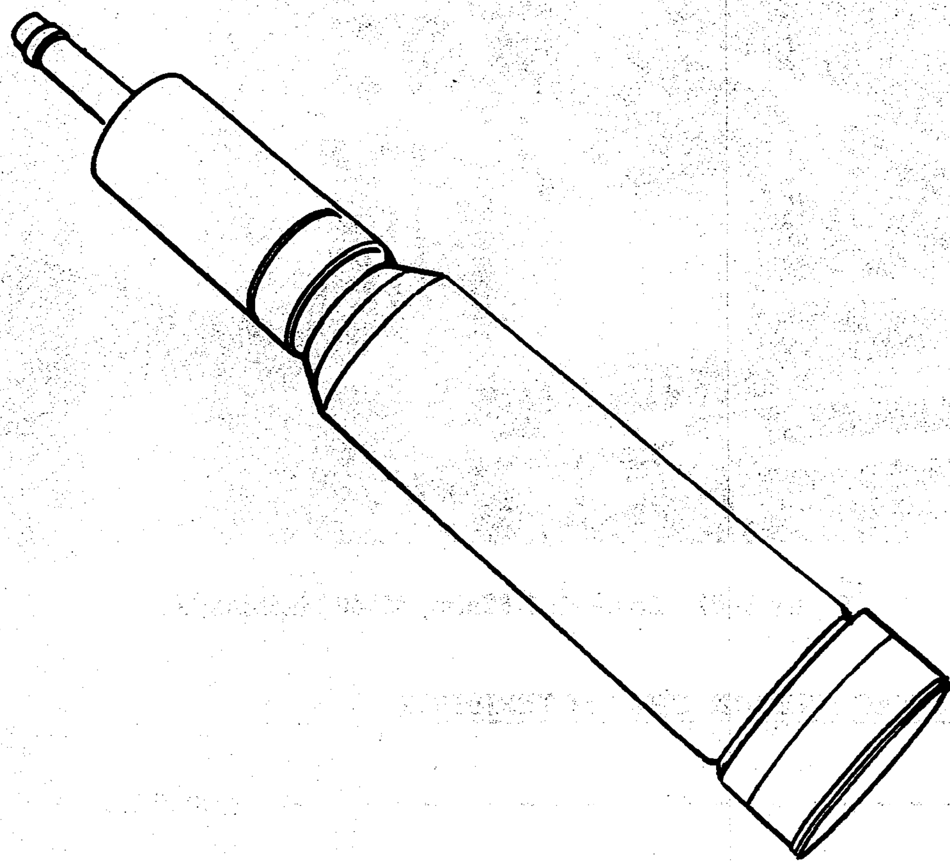


Figure 3-56. High Explosive Antitank Round (HEAT-T)

3.6.2 Loader's 7.62mm, M240 Machinegun

The 7.62mm, M240 machinegun shown in figure 3-57 is a lightweight, air cooled, gas-operated, belt-fed weapon which is externally mounted at the loader's station. The weapon fires from the open-bolt position and is fed from the left side. The ammunition is belted using the M13 disintegrating link. The weapon employs a spring-loaded ejector which ejects fired cases through a port in the bottom of the receiver. Links are ejected out of a port in the opposite side of the receiver from the direction of feed. A gas regulator is provided under the forward part of the barrel which may be adjusted to maintain the cyclic rate of fire when the weapon starts to malfunction due to fouling or to other adverse conditions.

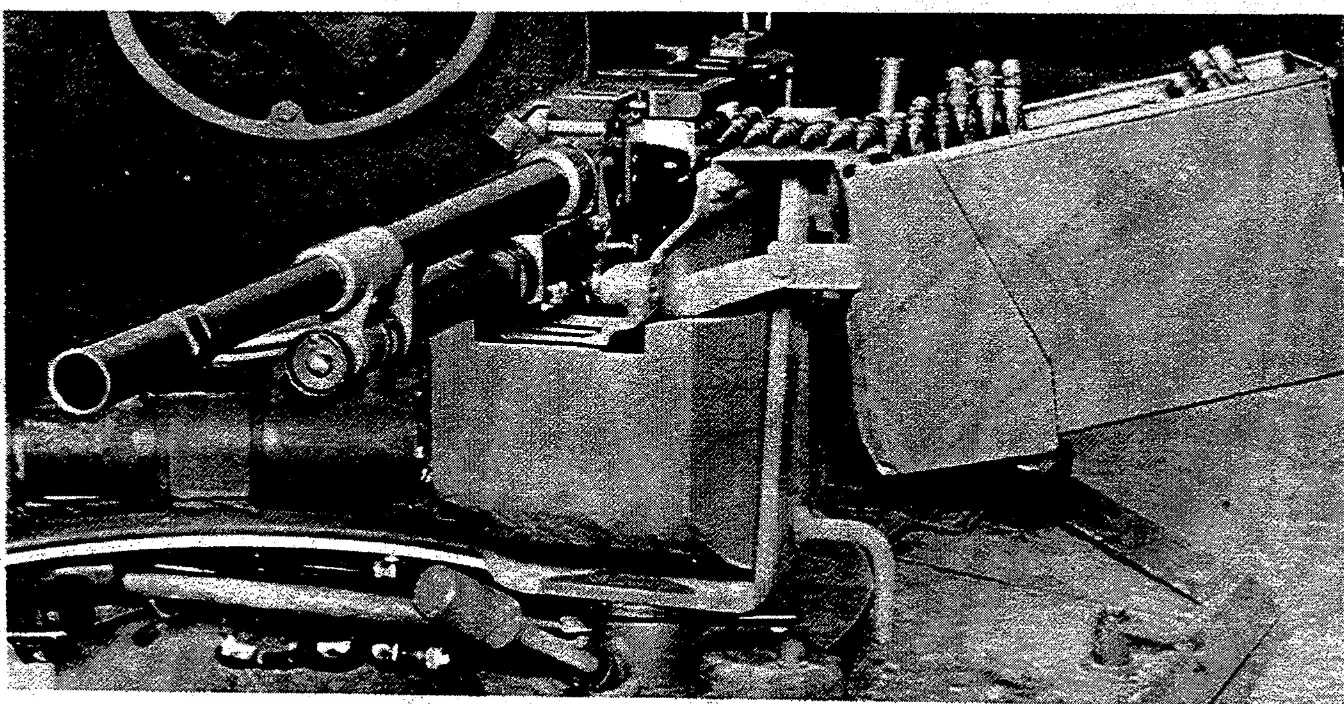


Figure 3-57. Loader's 7.62mm, M240 Machinegun

7.62mm, M240 MACHINEGUN CHARACTERISTICS

Weight	22.5 lbs
Length (overall)	41.3 in.
Length (barrel assembly)	24.8 in.

Type of operation	Gas (variable with three settings)
Type of feed	Disintegrating metallic link belt, M1A13
Muzzle velocity	2808 ft/sec
Cooling	Air
Cyclic rate of fire	560-980 rds/min

3.6.3 Commander's .50 caliber, M2 Machinegun

The .50 caliber, M2 machinegun shown in figure 3-58 is a recoil operated, belt-fed, air-cooled weapon which is externally mounted at the commander's station. The ammunition is belted using a metallic disintegrating link. By properly repositioning some of the component parts, the machinegun may be fed from either the right or left side. It is equipped with a M10 charger. The machinegun is a heavy barrel type designed for turret installations and can be fired using the manual mode in both the commander's closed hatch and open hatch positions.

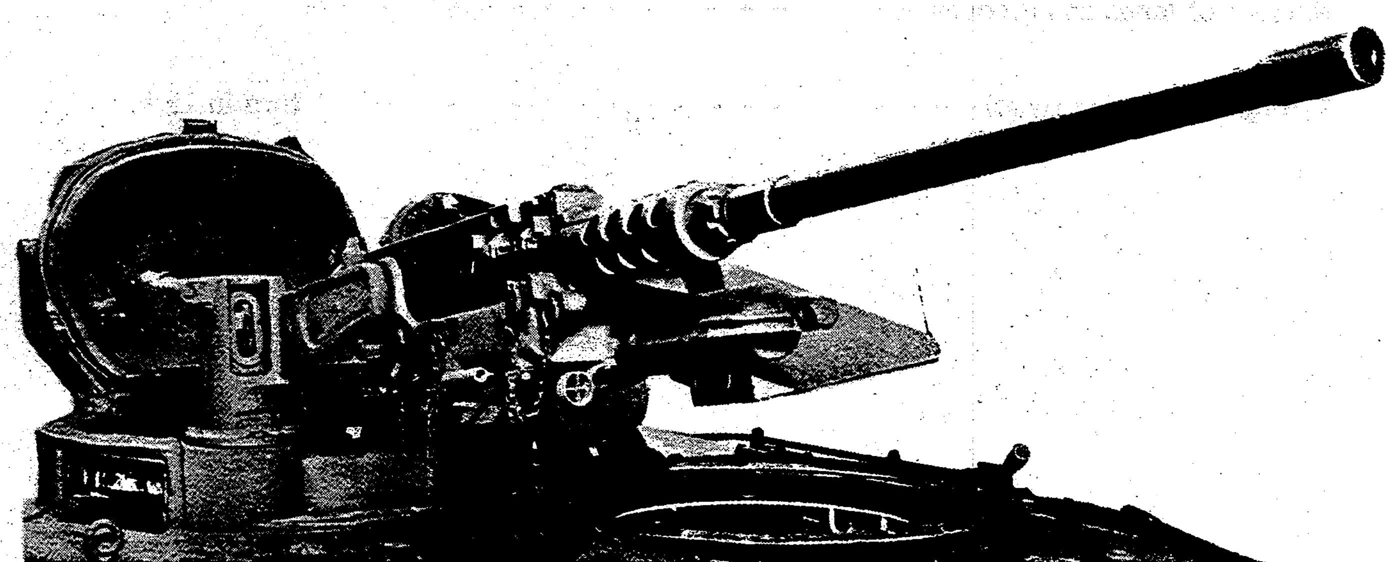


Figure 3-58. Commander's .50 Caliber, M2 Machinegun

.50 CALIBER, M2 MACHINEGUN CHARACTERISTICS

Weight (gun)	80 lbs
Weight (barrel)	28 lbs
Length (gun)	65.13 in.
Length (barrel)	45.0 in.
Feed	Disintegrating metallic link belt
Cooling	Air
Muzzle velocity	2930 - 3050 ft/sec
Rate of fire	450 - 555 rds/min
Number of lands and grooves	8
Rifling (right-hand twist)	1 turn in 15 in.

3.7 AUXILIARY AUTOMOTIVE SYSTEM

3.7.1 General Description

The Auxiliary Automotive System is defined as those tank hardware elements not directly mounted on or installed with the powerpack (except for alternator, starter, and powerpack electrical) but are necessary to the operation of the powerpack and vehicle. The System includes hull electrical, the fuel system, the fire protection system, crew compartment heating, the driver's station, driver's panels, driver's controls, and the Nuclear, Biological, and Chemical (NBC) System.

3.7.2 Fuel System

The fuel system shown in figure 3-59 provides sufficient fuel capacity to meet or exceed the cruising range requirements. Four fuel tanks are located in the hull and are armor protected to provide for the 205 mile operating range. Additional fuel volume is located in the sponson areas. All fuel cells are made from high density rotationally crosslinked polyethylene.

The front and engine compartment fuel tanks are molded from high density, cross linked polyethylene, and meet design requirements of MIL-T-46786 for improved durability and reliability. The front tanks and distribution system are compartmentalized to protect the crew. The tanks are covered with ceramic insulation material and nested in the front glacis, with interior bolted access panels. The sponson tanks are also constructed of molded high density cross linked polyethylene and surrounded by light armor to meet the requirements for small arms protection. Both engine compartment fuel tanks have drainports that are accessible from the outside of the vehicle.

The sponson tanks drain, by gravity, to the engine compartment tanks and do not have separate drain provisions. The engine is not fed fuel directly from the front tanks. A transfer system connects the front and rear tanks. During operation, the rear tanks are the fuel source for engine demand. Pressurization of fuel lines within the crew compartment and associated hazard is reduced since the transfer line will be activated only during non-combat operation when rear tank fuel levels are low. The selection of right or left front fuel tank and the concurrent sealing of the nonfunctioning tank lines is accomplished within the fuel transfer manifold. A single positive displacement pump is

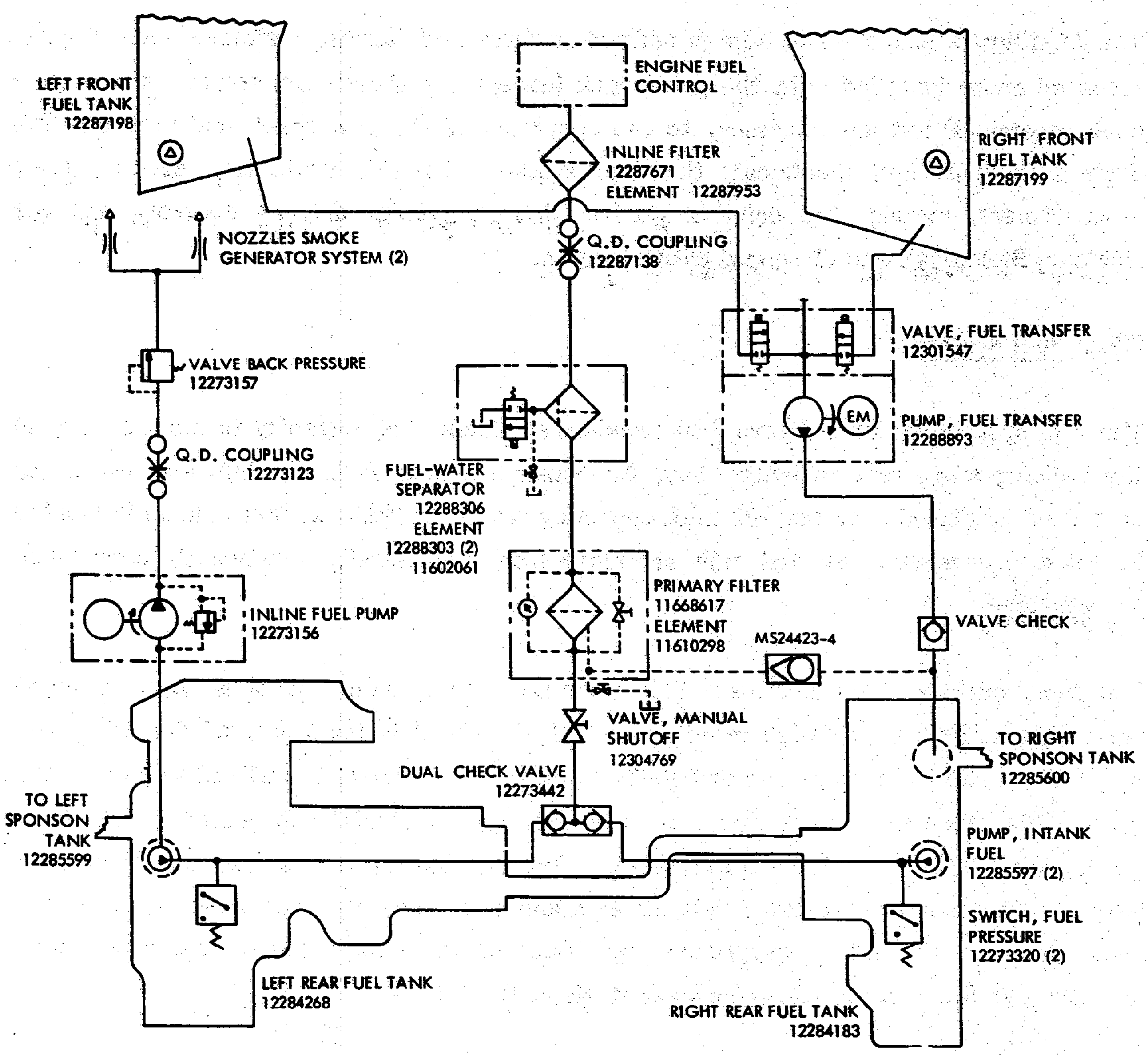


Figure 3-59. Fuel System Supply and Distribution Schematic

used for transferring the fuel. Vulnerability is reduced by locating front tank supply lines below the turret basket floor line but over the suspension components and well above the floor. An armored channel provides added spall protection for these lines in the crew compartment. Additionally, the front tank crossover (interconnection) is also compartmentalized to keep leakage from entering the crew area. To reduce fire vulnerability of the sponson-to-engine-compartment interconnections, flame arrestors are used. Fire resistant materials are used for the interconnect fittings between nonmetallic tanks. All tubing, fittings, and in-tank accessory hardware are corrosion resistant and conform to military specifications. Thermal insulation isolates the engine compartment tanks from direct exposure to radiated engine heat.

Conditioning of the fuel in the fuel/water separator unit includes the removal of contaminants as well as water. In order to extend the life of the fuel/water separator elements, a primary fuel filter is provided to extract large particles from the fuel. The coalesced water is automatically drained from the system during engine operation to reduce maintenance. Filler caps on the fuel tanks are designed for nonspill slope operation. Fuel tank filling may be accomplished by use of the two front and two rear fuel filler ports. For 50 gpm and faster fill rate, all four fill ports are used.

3.7.3 Fire Protection System

Crew protection is provided by a fully automatic fire detection and suppression system. Fire detection is accomplished with Infrared (IR) optical sensors and suppression with Halon 1301 agent dispensed by a fast acting solenoid valve. In addition, the crew safety is enhanced by a fire detection and suppression system for the engine compartment.

The crew compartment fire detection system will respond to an explosive type fire within 2 milliseconds. The fire suppression system will, within 100 milliseconds, extinguish the flame propagation before any explosion. The system uses dual spectrum infrared detectors, which are the most false alarm free detectors developed thus far. By sensing the heat radiation and the light or flame flicker these sensors:

- Will not false alarm with flashlight
- Will not false alarm with cigarettes, lighters, or matches
- Will not false alarm with sunlight
- Will not false alarm with metallic insignia or red clothing
- Will not false alarm with flashing lights

The sensors are designed to detect a cold fuel, pan fire of 18 inches diameter at a distance of 5 feet within 1.5 to 6 milliseconds. The crew and engine compartment fire sensors are identical configurations. The sensors are located so that the IR optical field of view encompasses and monitors all crew member areas and the engine compartment continuously. The fire suppression subsystem contains rapid-acting solenoid dispersion valves used with three nonshatterable receiver bottles, each containing seven pounds of Halon 1301 fire extinguishing agent.

The fire extinguishing system functions in two separate areas: the crew compartment and the engine compartment, as shown in figures 3-60 and 3-61. The fire extinguishing agent can also be manually released by the driver. The distribution of the Halon 1301 agent in the crew compartment after discharge does not exceed the guideline of 6 percent mean concentration for five minutes established by the Army Surgeon General.

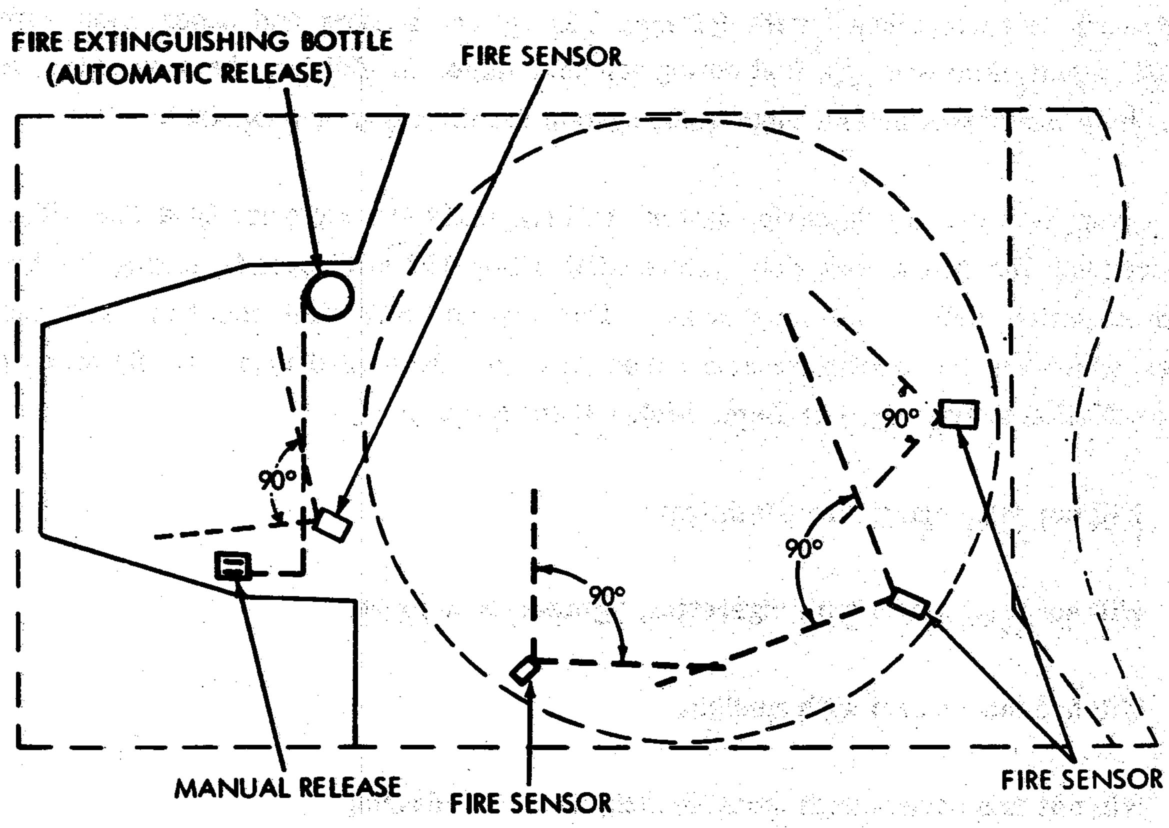


Figure 3-60. Crew Compartment Fire Detection/Suppression System

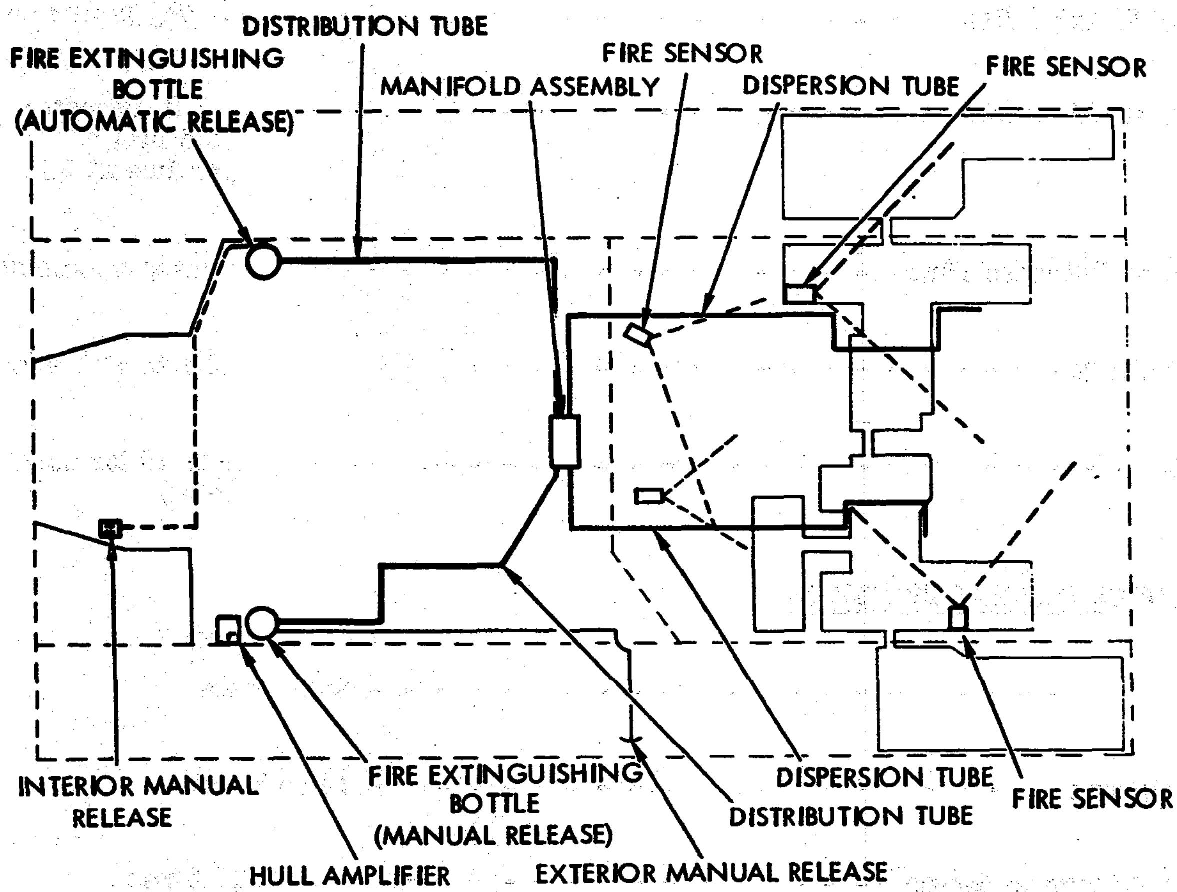


Figure 3-61. Engine Compartment Fire Detection/Suppression System

The engine compartment two-shot system has automatic detection and suppression discharging of one bottle assembly for the first shot. If a fire rekindles, the driver can release the second shot by actuating an electrical switch. In this latter case, the engine will shut down and a built in time delay subsequently discharges the second bottle. In addition, a manual discharge for the engine compartment first shot is provided for the driver at his station. A vehicle external handle mounted on the hull left side will discharge the second shot without engine shut down.

SENSOR CHARACTERISTICS

Type -	Dual optical IR
Number -	8
Spectrum (dual infrared) -	7 to 30 microns 0.8 to 1.0 microns

Optical Field of View	90 deg minimum
Sensitivity Threshold	1.5 ft diameter cold fuel pan fire at 5 ft
Explosion Response Time	2 msec maximum
Input Voltage	13.5 to 19.5 vdc
Weight	1 lb. (8 lbs max total)

AMPLIFIER CHARACTERISTICS

Type	Solid State
Input Voltage	18 to 30 vdc
Output Voltage to Sensor	13.5 to 19.5 vdc
Normal Operation Current Drain	350 milliamps
Valve Signal	10 amp for 150 msec into a one ohm load.
Weight	5 lbs max

3.7.4 Crew Compartment Heating/Ventilation

Crew compartment heating is provided by a 60,000 BTU multi-fuel personnel heater. The system has the capability to operate the 174 cfm heater/blower without operating the heater itself. This provides ventilation to the turret and driver. Figure 3-62 illustrates the ducting and control of heated or unheated air from the personnel heater.

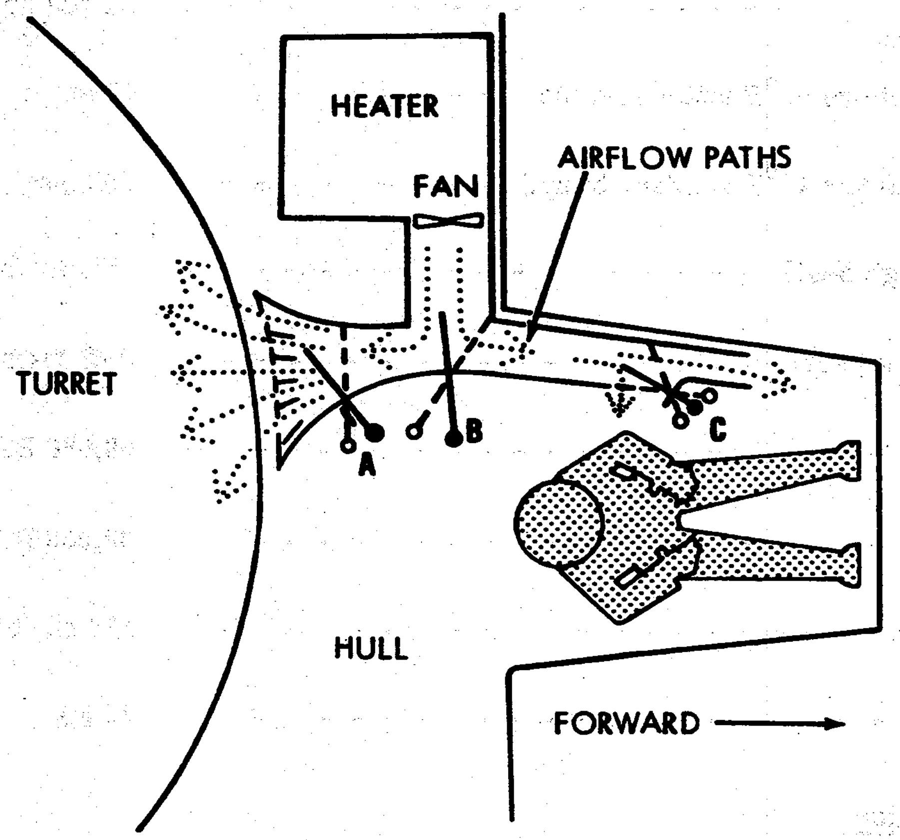


Figure 3-62. Personnel Heater Airflow Paths

Inspection of figure 3-62 reveals that the driver has control of three baffles. Baffle A and B (on the main air duct) directs the heater airflow to the turret only, the driver only, and varying combinations to both the turret and driver. The amount of air the driver has selected with baffles A and B then is further controlled by baffle C. Baffle C allows the driver to direct all airflow to his feet, all to his head and torso, or any combination thereof.

The maximum airflow measured at the driver's station, with the personnel heater air directed to the driver's outlet, is about 70 cfm. The air velocity past the driver is over 200 feet per minute when the air is directed out one opening. Thus, by the proper adjustment of baffles, the driver can obtain any desired air flow and velocity. The hot heater exhaust pipe has been routed through the sponson to avoid personnel contact.

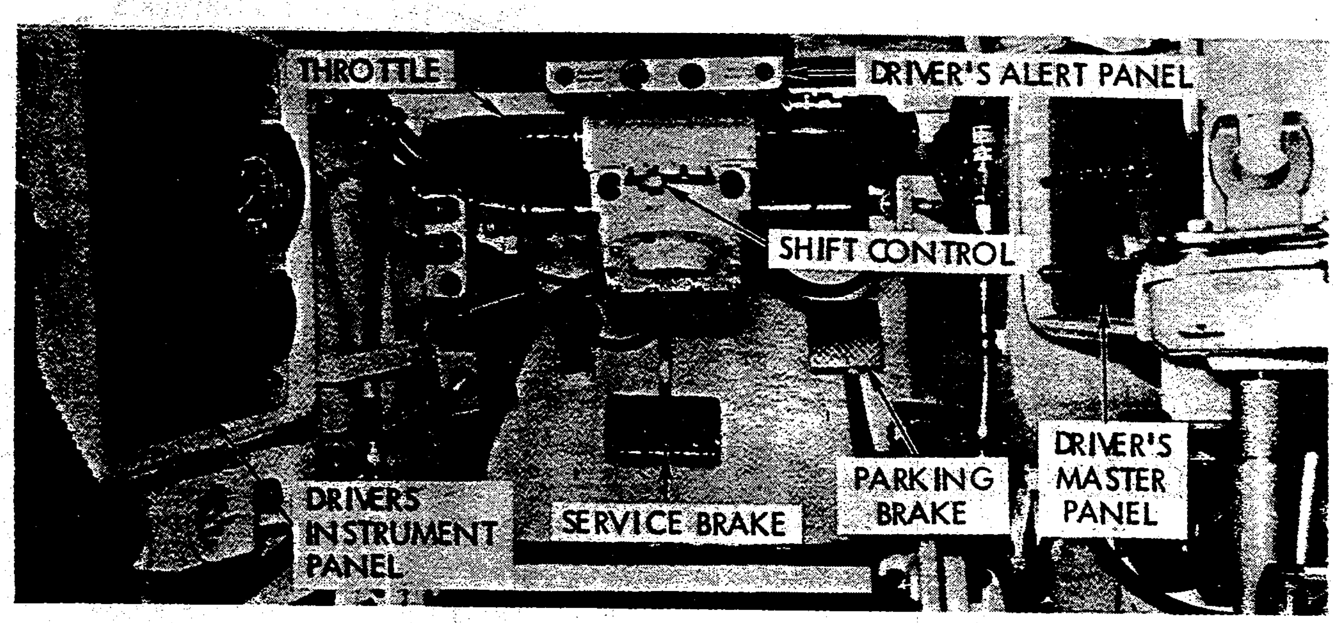
PERSONNEL HEATER CHARACTERISTICS

Voltage	24 vdc nominal
Current-Running (above 45°F ambient temp.)	15 amps
Current-Running (below 45°F ambient temp.)	20 amps
Fuel Flow Rate (high heat)	.085 lbs/min
Fuel Flow Rate (low heat)	.047 lbs/min
Heat Output (high)	60,000 BTU/hr
Heat Output (low)	30,000 BTU/hr
Air Discharge Rate	174 cu ft/min
Weight	35 lbs

3.7.5 Driver's Station.

The driver's station configuration as illustrated in figure 3-63 arranges the driver within the established spatial envelope and locates and orients controls and displays in an optimum relationship for both open and closed hatch driving.

The driver's seat is designed to accomodate 5th to 95th percentile crewmen in arctic gear. A large lever to the left of the seat permits low effort open- hatch/closed-hatch seat position changes. Seat adjustments are illustrated in figure 3-64. Seat height itself is adjustable to four positions by a tab located at the lower right of the seat. Both an upper backrest and hull mounted headrest also can be finely adjusted for visual alinement and general upper torso comfort. The seat can be moved to the open- hatch position without disturbing the closed hatch headrest setting. An adjustable lower lumbar support, controlled by a large knob on the lower left hand side of the seat, permits the driver to "dial in" the precise amount of lower back support that he desires. In the closed hatch position with the seat properly positioned, the driver then can easily and quickly adjust each of the three periscopes individually to his precise visual preferences.



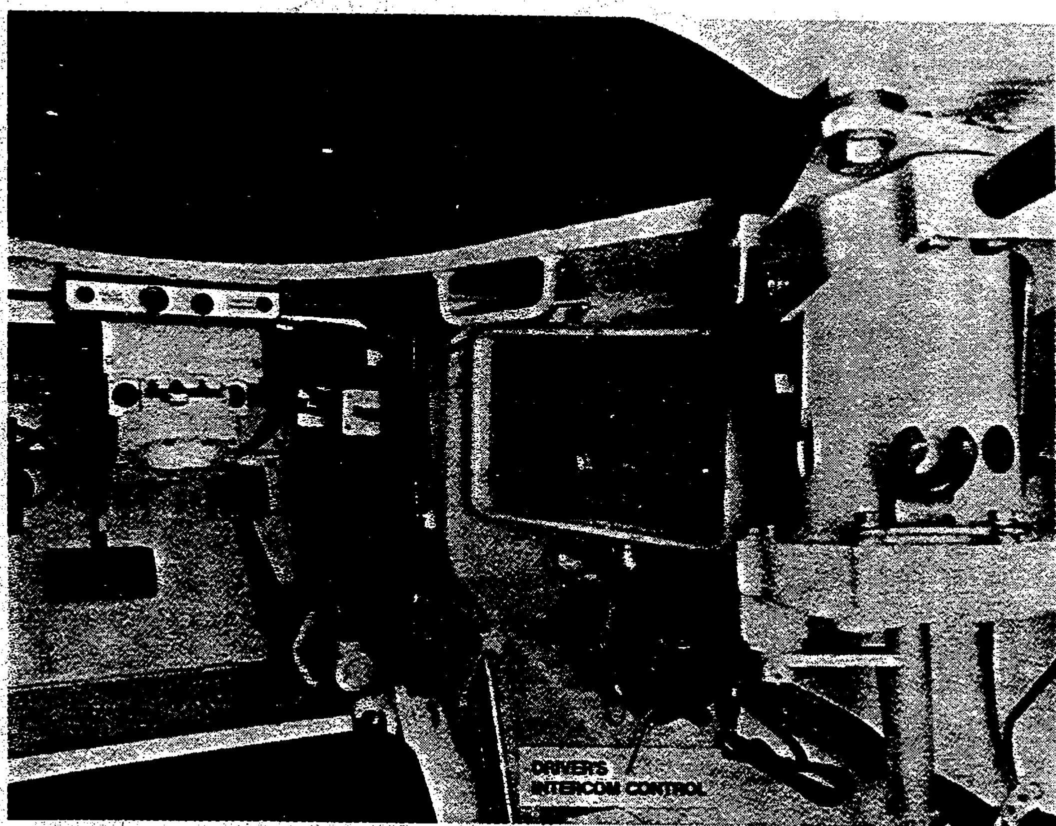


Figure 3-63. Driver's Station Arrangement

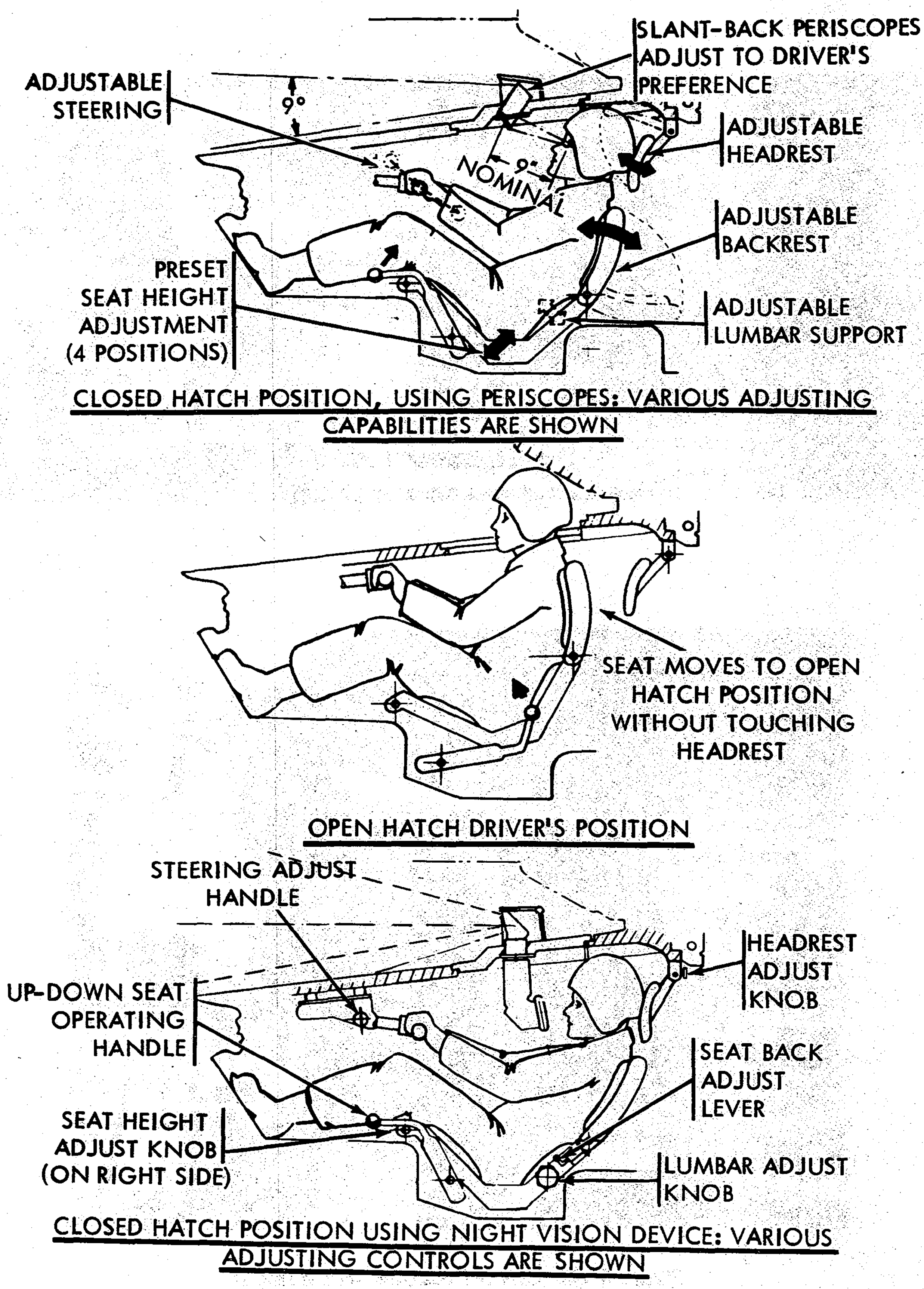


Figure 3-64. Driver's Seat Positions

Automotive related controls are designed to meet standards of simplicity, human compatibility, and integration. As an example, both throttle and steering controls have been incorporated into the T-bar, eliminating a separate accelerator pedal and thus providing more foot space. This T-bar/throttle assembly is adjustable from a stowed position to three positions in order to allow a natural hand and forearm position in both open and closed hatch driving. The hand throttles, utilizing motorcycle style grips, can be operated with either hand or both, as warranted by the situation. "Push-to-talk" pushbuttons are conveniently located on the hand throttle housing. These buttons permit the driver to key his intercom without removing his hands from the controls. The service brake pedal has been located in the floor area allowing braking with either foot. The shift selector is part of the T-bar/throttle assembly.

Panel warning lights are provided rather than gages for each critical function, based on ease of interpretation, attention getting value, and need for quantification used as prime criteria for each individual decision. The panels have been positioned sufficiently high in the station to provide good visual access to critical instruments and indicators in either closed or open-hatch driving modes. Automotive related displays and gages are grouped into a single functional presentation. The right side master panel is also configured in a functional format for open/closed-hatch accessibility and readibility. The master warning and master caution lights are given special prominence directly in the driver's forward field of view.

The driver's daily maintenance activities are made easier through the use of built-in-test-equipment and visual indicators. This reduces the time to perform daily crew checks of crew compartment filters, fluid levels, and fire extinguisher readiness.

The primary consideration in the design of the driver's hatch was safety and ease of operation. Figure 3-65 illustrates the driver's hatch opening mechanism. The structural design of the hatch mechanism and the safety factors utilized in the design of the internal gears and mechanisms provides maximum driver protection against any possible inadvertent closing of the hatch when the driver is operating open hatch. First, the spring loaded hatch stop lock automatically holds the hatch open since it has been opened completely. Should the driver for any reason not open the hatch completely, the rotating crank handle when released will snap into a detent which will lock the mechanism from rotating, even when subjected to a worst case lateral load. The driver's hatch operating mechanism

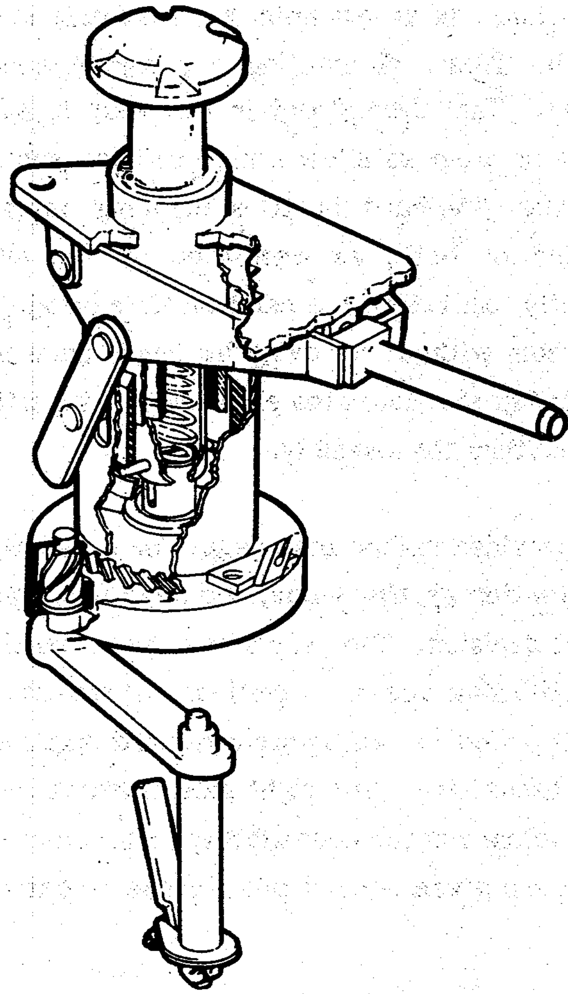


Figure 3-65. Driver's Hatch Mechanism

allows drivers to open the hatch in less than 4.0 seconds and close it in less than 3.0 seconds. The driver's hatch swings open to provide an unobstructed view over the right fender. Forces needed to open or close the hatch are within HFE requirements at the specified side and forward slopes. A standard seal bonded to the hatch seals the opening against water during rain and water fording operations.

For closed hatch day vision, the ten inch wide center periscope and the two seven inch side scopes with individually adjustable mirrors are located in the driver's hatch close to his preferred head position. The instantaneous field of view for the center periscope is approximately 9 degrees vertically and 45 degrees horizontally, while that for the side periscopes is 9 degrees vertically and 33 degrees horizontally. Excellent overlapping fields of view are attained with minimum head motion. The driver's horizontal vision envelope is shown in figure 3-66. All unity vision devices contain filters to protect the crew's eyes from possible damage from neodymium laser light. A foot-operated washer and hand-operated double wiper are provided to clean the ten-inch center periscope. If the center periscope is damaged, an adapter is provided to allow fitting the seven-inch scope in its place.

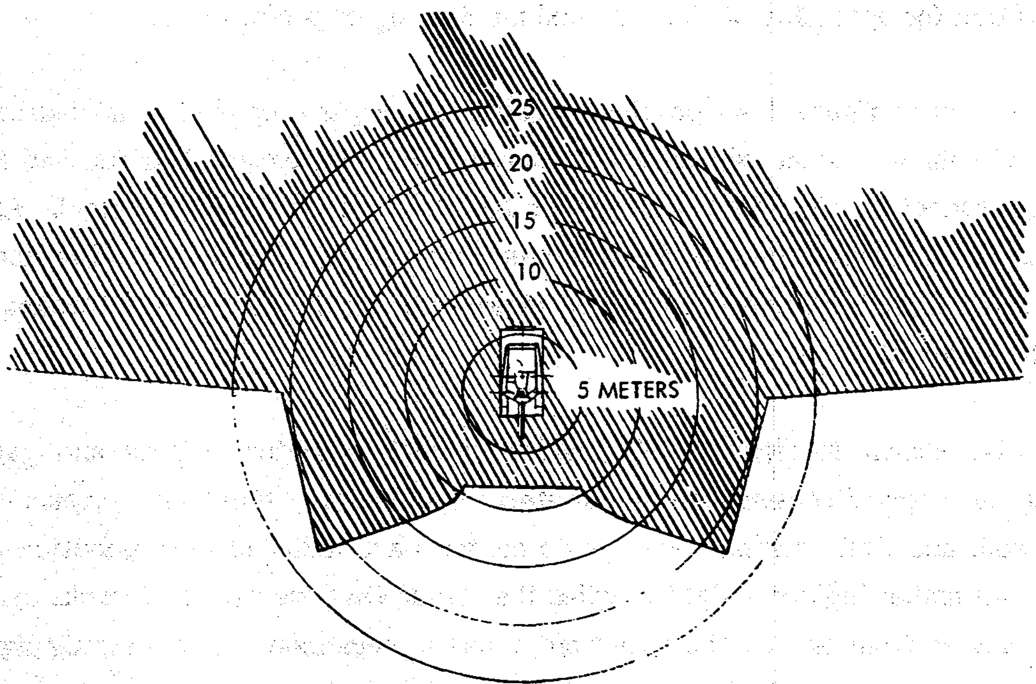


Figure 3-66. Driver's Unity Day Vision

For closed-hatch night viewing, the night vision periscope, with adapter, can be quickly removed from its stowage box (under loader's seat) and clamped in place of the center scope. Its position facilitates a comfortable three-to-six inch eye relief for the driver, which provides a nominal 35 degree vertical and horizontal field of view at 5 inch eye relief. The horizontal field of view can be increased to 135 degrees by turning the entire periscope $\pm$ 45 degrees.

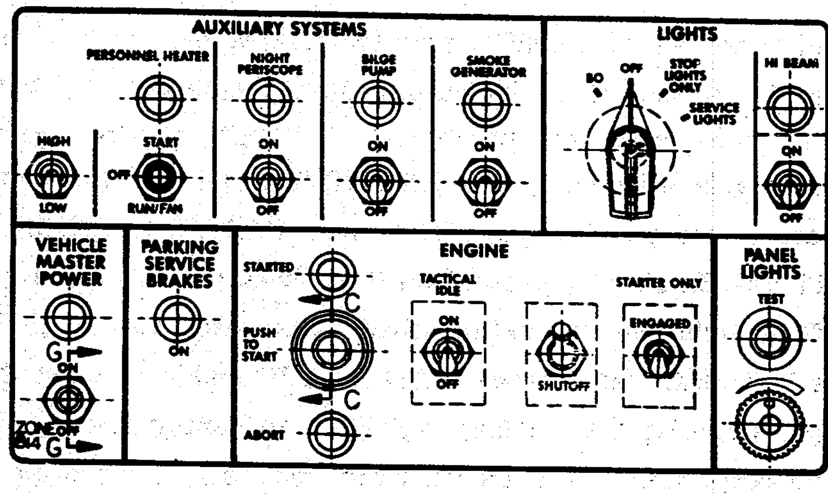
The hatch opening has been sized so that the driver, and other crew members as required, can exit the hatch under emergency situations, i.e., the vehicle overturned in such a manner as to prevent escape from other hatches. The driver can exit through the hatch even when the gun is immobilized directly over the hatch and fully depressed, or when the hatch must be opened and exited without removing an installed night vision periscope.

3.7.6 Driver's Panels

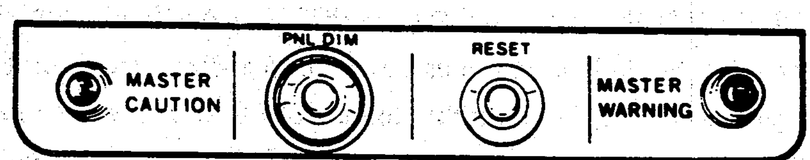
Driver's Master Panel (DMP) and Driver's Instrument Panel (DIP) are provided in the driver's station for operation of the tank and monitoring of performance.

The DMP shown in figure 3-67 provides electrical circuitry, controls, and indicators for operation of vehicle master power, engine automatic start, external lights, and auxiliary systems (personnel heater, night periscope, bilge pump, and smoke generator). An engine starter only control is included to check starter performance, engine oil or fuel leaks, etc. A red warning light is provided to ensure release of parking and service brakes before moving of the vehicle.

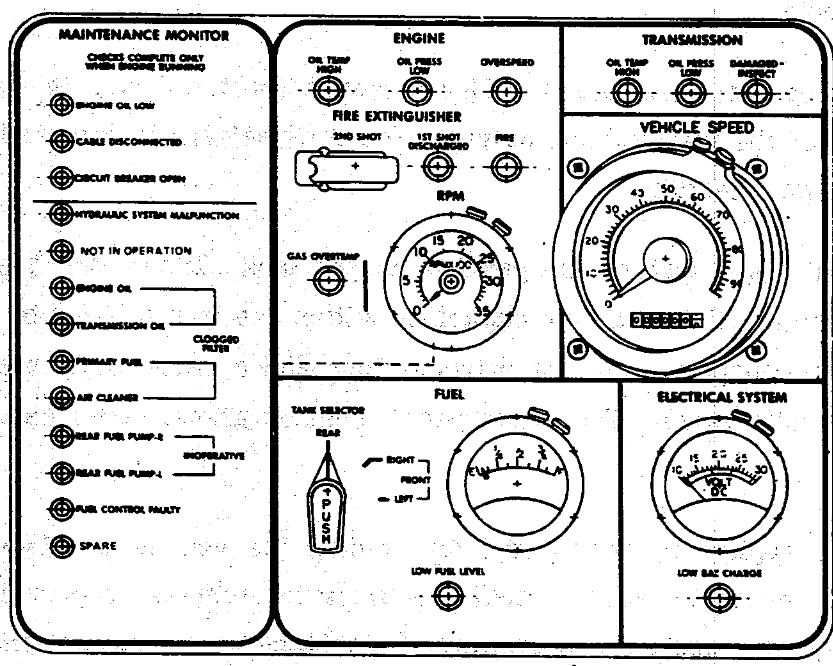
The DIP also shown in figure 3-67 provides visual indicators (lights and gages) for monitoring of engine/transmission parameters, fuel status, electrical system voltage, vehicle speed, and fire warning. Fuel pump controls are included in conjunction with the fuel gage. An amber indicator light notifies the driver that the rear fuel tanks are low on fuel and transfer from one of the two front tanks is necessary. Red warning lights, the engine power turbine speed indicator and the vehicle speedometer/odometer warn the driver of abnormal (pressure, temperature, RPM) operation of the engine and transmission. A voltmeter displays electrical system voltage, and an amber indicator light notifies the driver of low battery state-of-charge when the engine is not running. A flashing red light warns the driver of an engine compartment fire while a second amber light indicates that the first fire extinguisher bottle was discharged. A guarded toggle switch is provided to shut down the engine and, after a time delay, actuate a second fire extinguisher bottle should the fire restart or the first bottle fail.



DRIVER'S MASTER PANEL



DRIVER'S ALERT PANEL



DRIVER'S INSTRUMENT PANEL

Figure 3-67. Driver's Panels

The maintenance monitor section of the instrument panel provides malfunction indications (LED's) for 12 vehicle functions. These indicators allow the driver to monitor various hull/powerpack maintenance required parameters without access to the engine compartment. Should a malfunction occur (i.e. ENGINE OIL-LOW) an amber maintenance indicator will illuminate on this panel, along with a large MASTER CAUTION amber light (located on the ALERT PANEL directly in front on the driver) for high visual prominence. The MASTER CAUTION light can be extinguished by a reset button on the ALERT PANEL; however, the individual maintenance indicator will remain on until the fault has been corrected. Proper servicing, i.e., adding engine oil, will extinguish the ENGINE OIL - LOW indicator. The large MASTER WARNING red light, also located on the ALERT PANEL directly in front of the driver for high visual prominence, illuminates simultaneously with any of the red warning lights on the instrument panel. The reset capability for both the MASTER CAUTION light and the MASTER WARNING light prevents any masking condition, should a second fault occur prior to the first problem being cleared. The ALERT PANEL contains a PNL DIM pushbutton switch to dim the MASTER CAUTION and MASTER WARNING lights. Although these lights are designed to come on at full brightness whenever VEHICLE MASTER POWER is applied, the driver may opt for a lower brightness level during night time operations.

3.7.7 Driver's Controls

The electrical shift control assembly provides a means for the driver to change speed ranges and direction of the transmission output. The shift pattern is detented to prevent inadvertent speed range selection.

Two fully independent brake systems are provided on the tank. The service brake controls the vehicle deceleration to the maximum capability within the transmission by means of a centrally located brake pedal about the driver's floor and a cable apply system to the transmission power brake valve. The brake pedal location allows equal ease of use by either foot.

The parking brake is applied by foot pedal for holding the vehicle on slopes up to 60 percent. A hydraulic modulator valve actuates a hydraulic cylinder to provide transmission brake lever travel and mechanical advantage for parking brake application.

The service brake control system provides a return force on the pedal for brake feel and a smooth braking action. An independent parking brake control system is provided which may be used as an emergency brake system if the service brake control system fails.

An integrated steer/throttle control is provided. This unique combination eliminates floor mounted controls and provides for improved driver response in both open and closed hatch modes of operation. The steering and throttle are both adjustable for 5th to 95th percentile crew members, a feature not normally provided in combat vehicles. Intercom buttons are provided for use by either thumb without removing the hands from the integrated steer/throttle control.

The steering control provides infinitely variable steer commands to the transmission by turning the steer/throttle bar up to 25 degrees from center. Throttling is accomplished by twisting the bar grips, much like a motorcycle, up to 60 degrees rotation for full throttle. The throttle can be operated by either one or both hands while steering. The steer handle position is adjustable for seat-up and seat-down positions by providing three steer/throttle bar locations and a stowed position which can be selected by the driver. Under normal operating conditions, return springs provide a steering feel and return the steer bar to the neutral centered position.

3.7.8 Nuclear, Biological, and Chemical (NBC) System

Nuclear, biological, and chemical protection is provided on an individual basis by a ventilated face piece (VFP) and protective overgarment. Protection is also provided on a collective basis by maintaining the crew compartment above ambient pressure through the use of crew compartment seals and filtered air. The temperature of the filtered air is controlled to protect against heat stress.

The NBC system shown in figure 3-68 uses engine bleed-air. The bleed-air is passed through an air cycle pack where it is cooled by a heat-exchanger and an expansion turbine. The cooled bleed-air, goes to the NBC filters where the contaminants are removed prior to entering the crew compartment. This air is routed to the ventilated face piece (VFP), the air cooled vest (ACV), and the crew compartment.

The NBC protection system is shown in figure 3-69. High pressure and temperature bleed air from the P3 stage engine bleed port is regulated by means of a dual differential pressure regulator and shutoff valve. During normal operation the regulator is set to 44 $\pm$ 4 psig. During low engine power setting operation with heavy hydraulic loading, a dual differential pressure regulator is automatically set to 16 $\pm$ 2 psig. The high temperature bleed air is first cooled by a precooler using ambient air drawn through the primary heat exchanger as a heat sink. The bleed air then enters a pressure regulating and shutoff valve, where it is regulated to 35 $\pm$ 2 psig for engine settings above tactical idle.

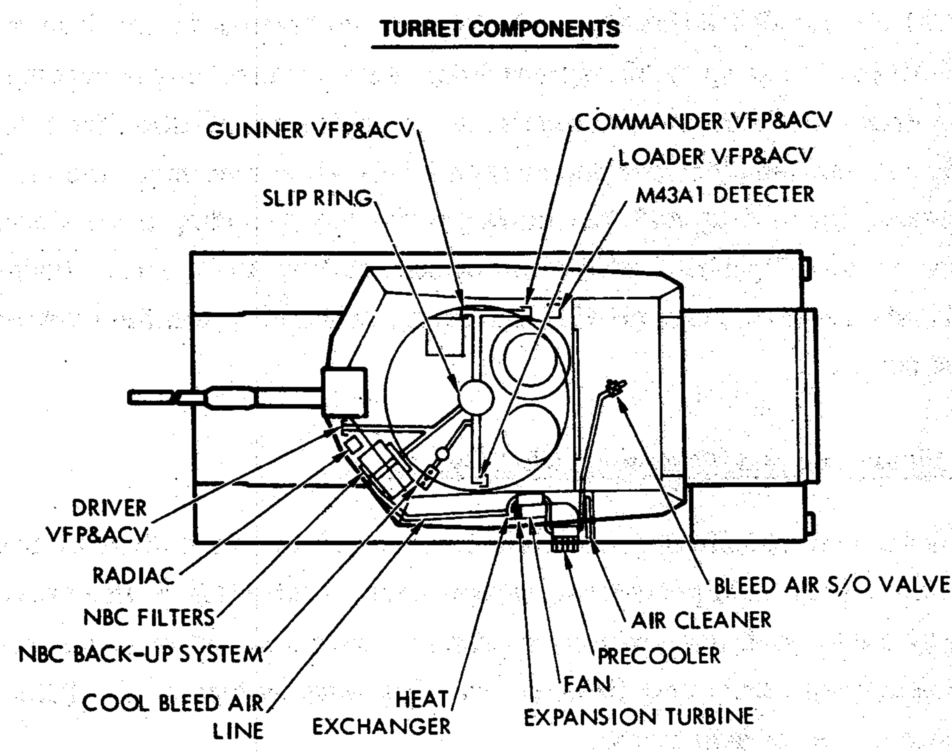


Figure 3-68. Nuclear, Biological, and Chemical (NBC) System

The bleed air then passes through a venturi designed to limit the bleed flow extracted from the engine during temperature control subsystem operation. The bleed air enters a refrigeration unit where the air is further cooled by a primary heat exchanger which uses ambient air as a heat sink. Water vapor in the bleed air is condensed in a counterflow condensing heat exchanger as cold turbine discharge air further cools the humid bleed air. The entrained water is removed in a high pressure water extractor and sprayed on the cold side of the primary heat exchanger through the cooling air duct, enhancing the cooling capacity of the primary heat exchanger during humid ambient conditions.

The bleed air next passes through the air cycle machine turbine section, where energy is extracted from the air to drive the ambient air fan which loads the turbine. The fan induces flow through the ambient air sides of the heat exchanger and exhausts the

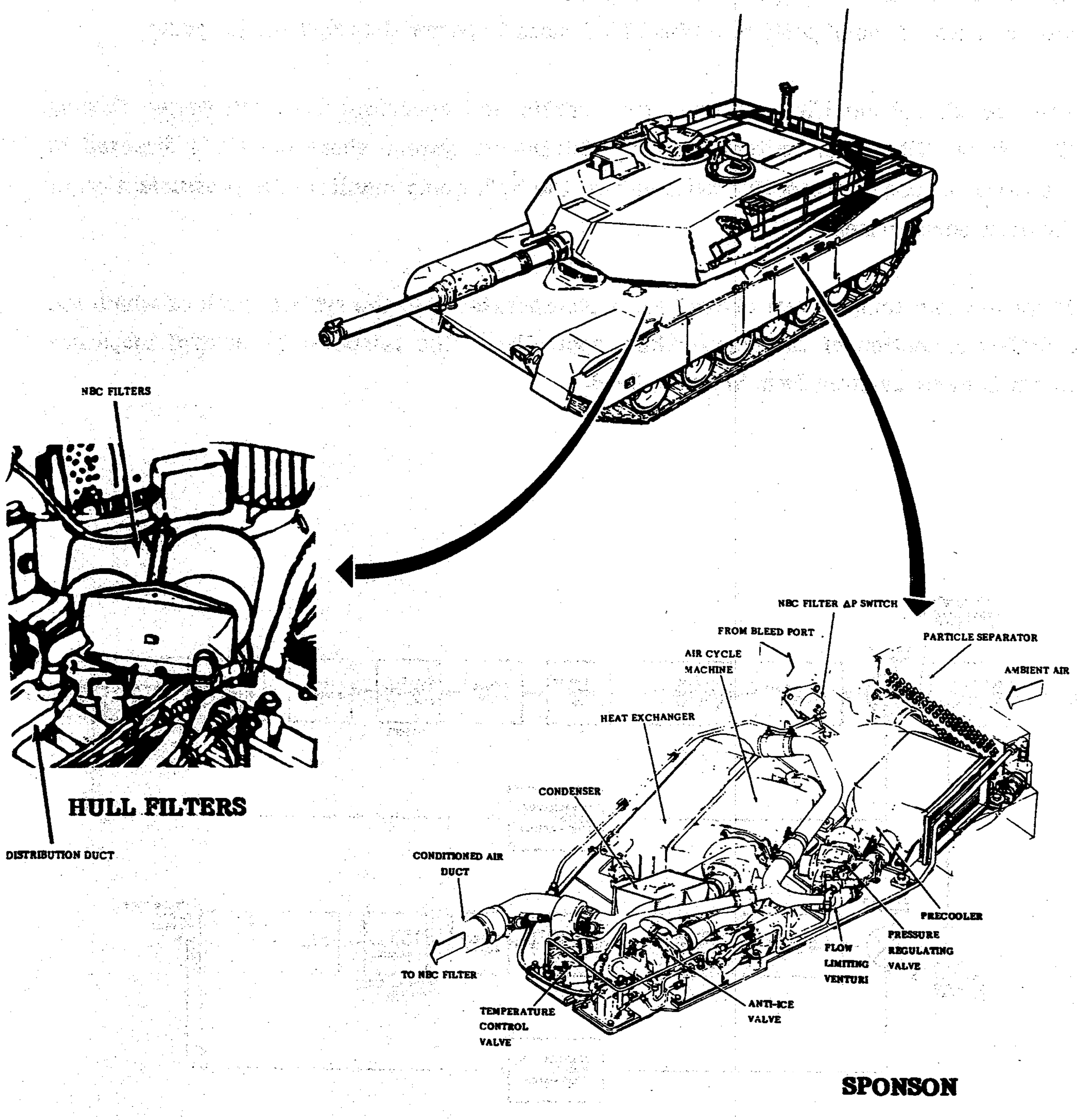


Figure 3-69. NBC Protection System

ambient air through the precooler then overboard through the ballistic grille. The energy extracted from the high pressure bleed air to drive the fan and the subsequent expansion through the turbine result in cooling of the bleed air.

To avoid contamination of the heat exchanger and erosion of the fan, the outside air is filtered by an inertial-type particle separator located at the ambient air inlet to the sponson area. A small portion of bleed air is used to power the scavange jet pump.

The cooled, dehumidified air from the turbine and condenser heat exchanger flowing through the NBC filters enters the tank distribution system where the air is directed to the crew members' protective suits and to the bulk dump manifold for pressurization of the crew compartment.

There are two temperature control loops incorporated into the system, both of which use a different section of the temperature controller. The temperature control loops are shown in block diagram form in figure 3-70.

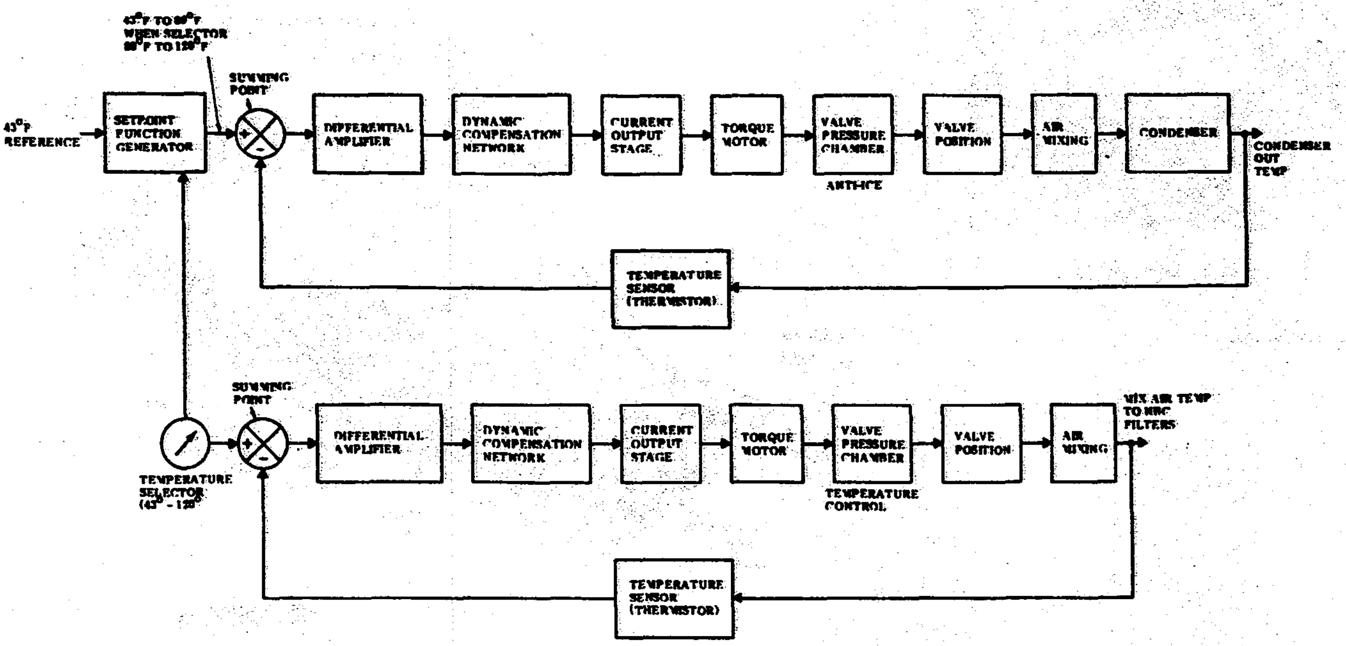


Figure 3-70. Temperature Control Block Diagram

The anti-ice temperature control loop, incorporating a temperature sensor and a temperature control valve, limits the minimum temperature at the sensor to approximately 43°F (the control set point) by adding moderate temperature air at the turbine discharge. The main purpose of this loop is to prevent icing in the condenser section and downstream ducting and to maintain a maximum efficiency in the water removal circuit. If condenser icing does build up, resulting in an excessive condenser pressure drop or ΔP, a pneumatically actuated anti-ice servo valve automatically modulates the anti-ice valve until a normal condenser ΔP is attained. This is an automatic protective circuit built into the temperature control logic. The anti-ice control loop also responds to signals from the temperature selector when more heating is required during cold day operation. When 80°F to 120°F is selected for the NBC filter inlet temperature control loop, the anti-ice temperature is increased proportionally from 43°F to 80°F which increases the supply temperature without sacrificing water removal efficiency.

The NBC filter inlet temperature control loop allows the crew to set the NBC filter inlet temperature (and thus the temperature to the crew members' suits). This control loop which provides reheat during humid conditions and comfort for the crew members, incorporates a temperature sensor, a temperature control valve, and a temperature selector. The selector located on the commander's panel provides a control selection range of 43°F to 120°F.

The NBC filters are supported by the support assembly. A differential pressure switch is used to detect an excessive differential pressure across the filters, indicating a need for replacement. The support assembly incorporates a double seal with the annulus between the seals vented to the air cycle machine compartment which is at a lower pressure, relative to the filter inlet air supply duct (and the compartment air pressure); therefore any leaks in the manifold/filter seals are exhausted and never enter the crew compartment.

The tank distribution system directs air to the crew members' protective suits and also to the bulk dump manifold. The airflow supplied by the system is used to pressurize the crew compartment slightly, thereby precluding the entry of outside air. A differential pressure switch located in the compartment is provided to alert the crew if loss of compartment pressurization occurs.

In the event of a malfunction that would preclude operation of the NBC system, another system provides recirculated filtered air to each crew members' VFP.

The crew compartment uses an AN/VDR-2 radiac to detect low threshold gamma radiation. One DS2 decontaminating apparatus, ABC-M11, is stowed between the commander and loader, and one is stowed in each cargo rack box. The AN/VDR-2 radiac, mounted on the hull floor at the driver's station, operates using the tank electrical system used. Its alarm is connected to the tank intercom system. Two BA-3202 batteries are provided for portable operation of the AN/VDR-2 radiac. One chemical agent detector kit is provided to verify decontamination/purging (safe to unmask).

3.8 SPECIAL EQUIPMENT AND KITS

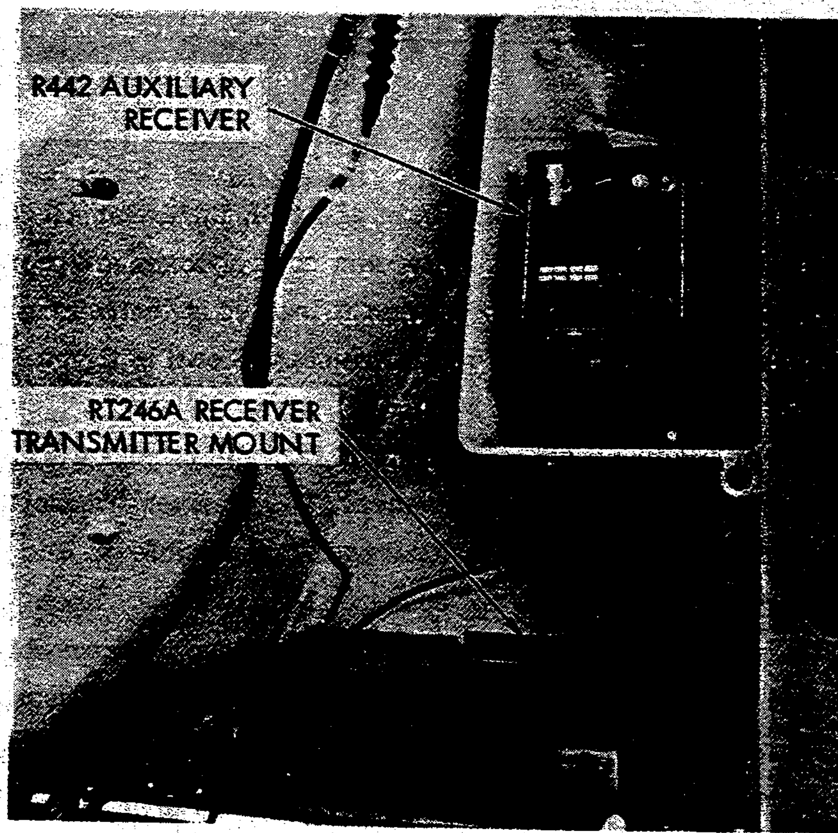
3.8.1 Communications System

The communication system consists of the GFE Radio Set AN/VRC-12 or AN/VRC-64 and the Intercom Set AN/VIC-1(V). Intercom control boxes are provided in each crew station and transmitter frequency selector box is located in the commander's station. Installation of the communications system in the vehicle is shown in figure 3-71.

Integration of the communication system into the vehicle installation provides accessibility of controls and ease of maintenance. The receiver/transmitter and auxiliary receiver are located in the loader's station readily accessible to the loader thus relieving the commander of the burden to operate the radios. Each station within the crew compartment except the loader's station has readily accessible intercom switches that permit the crewman to perform his normal duties while using the intercom, e.g., the gunner's intercom switch is mounted on his foot rest. Controls for the intercom are readily accessible at each crew station while frequency selection controls are provided for the commander. An NBC alarm can be heard in the intercom system in the event of an NBC attack. The alarm can be muted by a pushbutton on the commander's panel. Frequency changes can be made by the loader at the transmitter, therefore a frequency control box is eliminated. The radio antennas are mounted on opposite rear corners of the turret bustle providing maximum separation to minimize radio frequency transmitting interference and eliminating physical interferences with the loader's or commander's machinegun. The radio transmitting antenna cables are shielded to minimize EMI/EMC problems. Radio cables are routed through channels where feasible for additional shielding to ensure system compatibility. Provisions have been included for installation of two T-SEC/KY-57 security units in the commander's station, and related amplifiers are incorporated into the transmitter and receiver mounts.

3.8.2 Water Fording

The M1A1 Tank can ford streams up to 4 feet deep with no other action required than to operate with closed drain valves. The drain valve controls, located on the driver's right, open and close the crew and engine compartment drain valves independently. The valve handles are lifted to open and are retained by latching levers. The latching levers are spread open to release the handles for closing the valves.



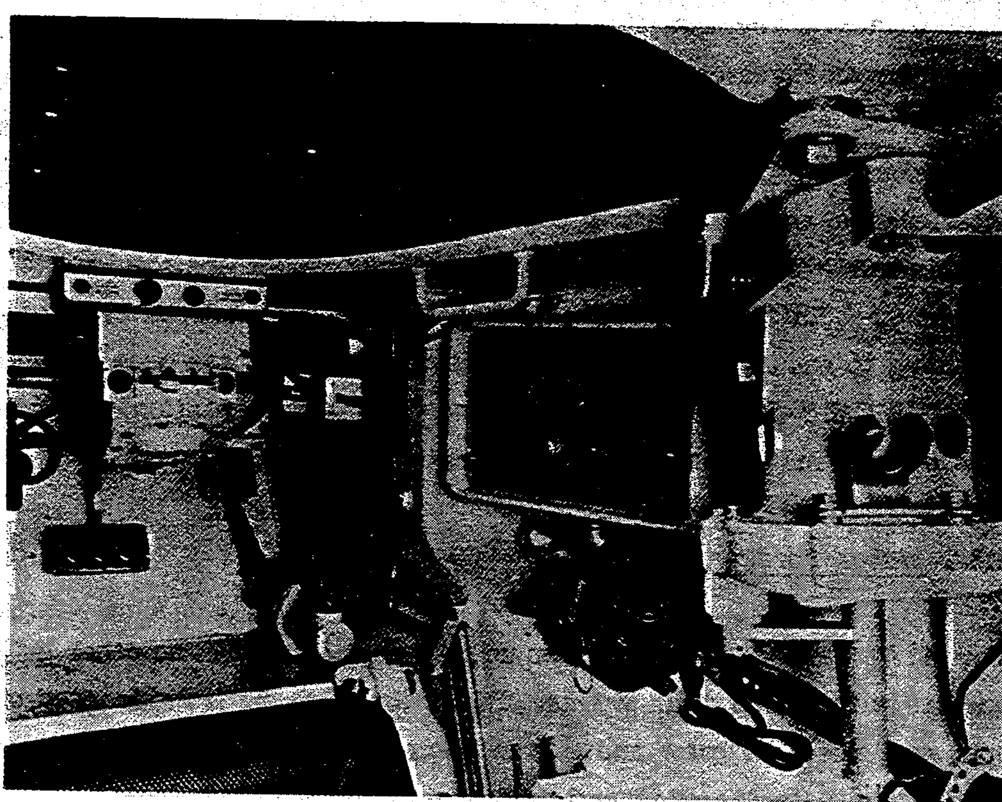
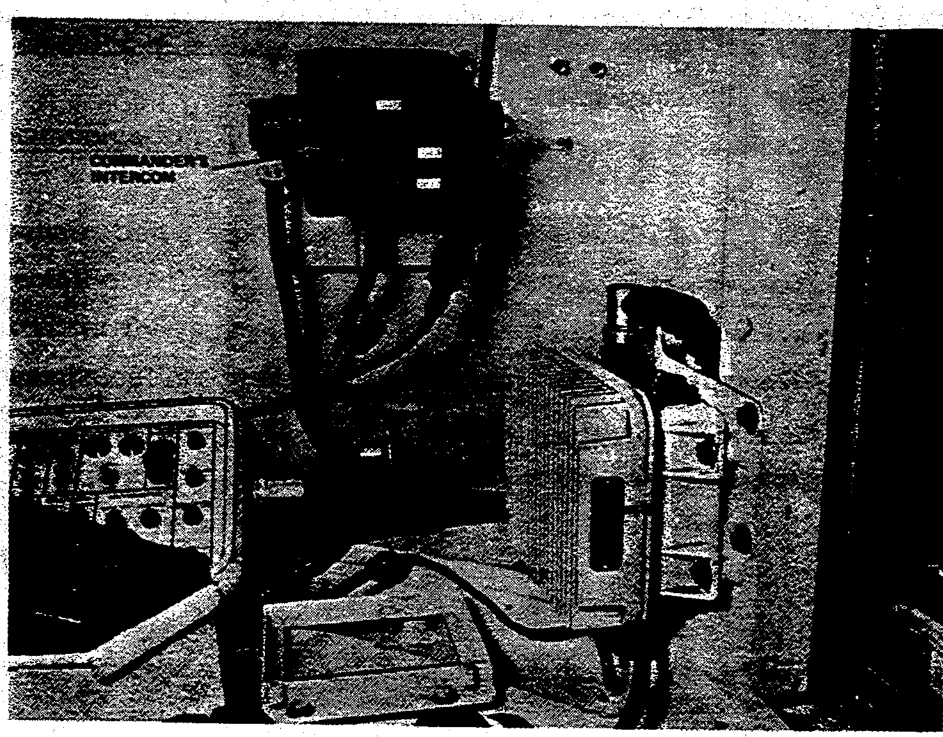


Figure 3-71. Communications System Installation



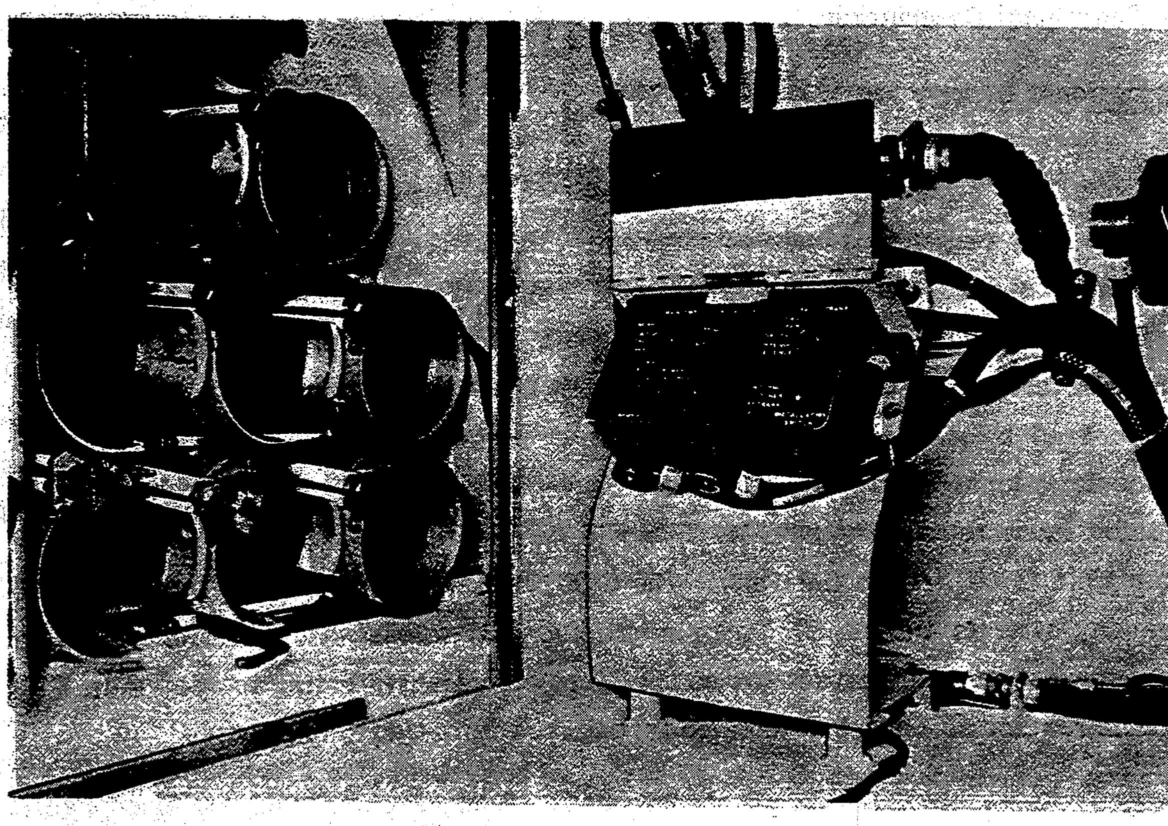


Figure 3-71. Communications System Installation (Continued)

The crew compartment has one poppet type valve located on the left forward side of the hull and is closed for fording. Drainage in the right side is removed by using a bilge pump. The engine compartment has a sliding port valve on each side of the hull for fast removal of water after fording.

3.8.3 Cold Temperature Operation

The M1A1 Tank has the capability of starting in cold climates down to -25°F without external aids. However, all cold temperature operation is enhanced with the addition of a fuel line heater, main battery heater, ECU battery heater, and elevation servo valve heater.

Vehicle operation between the temperatures of -60°F and -25°F is possible if an external power source is used to power the heaters for one hour prior to vehicle starting.

3.8.4 STE-M1/FVS Test Set

3.8.4.1 Functional Description

The Simplified Test Equipment test set STE-M1/FVS, (used to test derivatives of the Abrams and Bradley vehicles) is used to support the M1A1 Tank. The STE-M1/FVS is an automated electronic test set which consists of a Vehicle Test Meter (VTM), Controllable Interface Box (CIB), Set Communicator (SET COM), and associated adapters and cable assemblies to interface the test set with the tank's LRU's and harness connectors. This equipment is used by maintenance personnel at Organizational Level Maintenance to checkout the functional operation of the various vehicle systems, and to "troubleshoot" malfunctioning subsystems. The STE-M1/FVS will fault isolate to a malfunctioning Line Replaceable Unit (LRU) within the Tank. The STE-M1/FVS performs an automatic self-test whenever power is turned ON, with additional self-testing or confidence testing available upon request. The test set is also used for performance testing to determine the overall vehicle readiness. During automatic testing, the following may occur:

- o Instructions may be issued by the test set on the alpha-numeric display of the SET COM requiring supplementary action such as connecting or disconnecting cables. Testing stops at this point until the actions are completed.

- o The test set may request a visual observation and response from the operator. A response must be made before the test will continue.

- o At the end of the test, the test set will display either a "No Faults Found or indicate a faulty condition.

3.8.4.2 Physical Description

The STE-M1/FVS test set shown in figure 3-72 is contained in 7 transit cases. Two transit cases contain the electronic assemblies (VTM, CIB, SET COM, etc.); the other 5 transit cases contain electrical adapters and cable assemblies for testing the M1A1 Tank subsystems.

3.8.5 <u>DSESTS-M1/FVS Test Set</u>

3.8.5.1 Functional Description

The Direct Support Electrical Systems Test Set, DSESTS-M1/FVS, is a multi-tactical vehicle system test set to be used by Direct Support maintenance personnel for fault isolation of defective Line Replaceable Units (LRUs) removed from the M1A1 Tank. The M1A1 Tank system is automatically selected via electrical key coding within the LRU's. The following tank LRU's can be tested by the DSESTS-M1/FVS Test Set:

Turret Networks Box (TNB)
Line-of-Sight Electronics Unit (LOS-EU)
Gun/Turret Drive Electronics Unit (GTD-EU)
Commander's Weapon Station Power Control Unit (CWS-PCU)
Computer Electronics Unit (CEU)
Computer Control Panel (CCP)
Laser Range Finder (LRF)
Hull Distribution Box (HDB)
Driver's Instrument Panel (DIP)
Driver's Master Panel (DMP)
Electronic Control Unit (ECU)

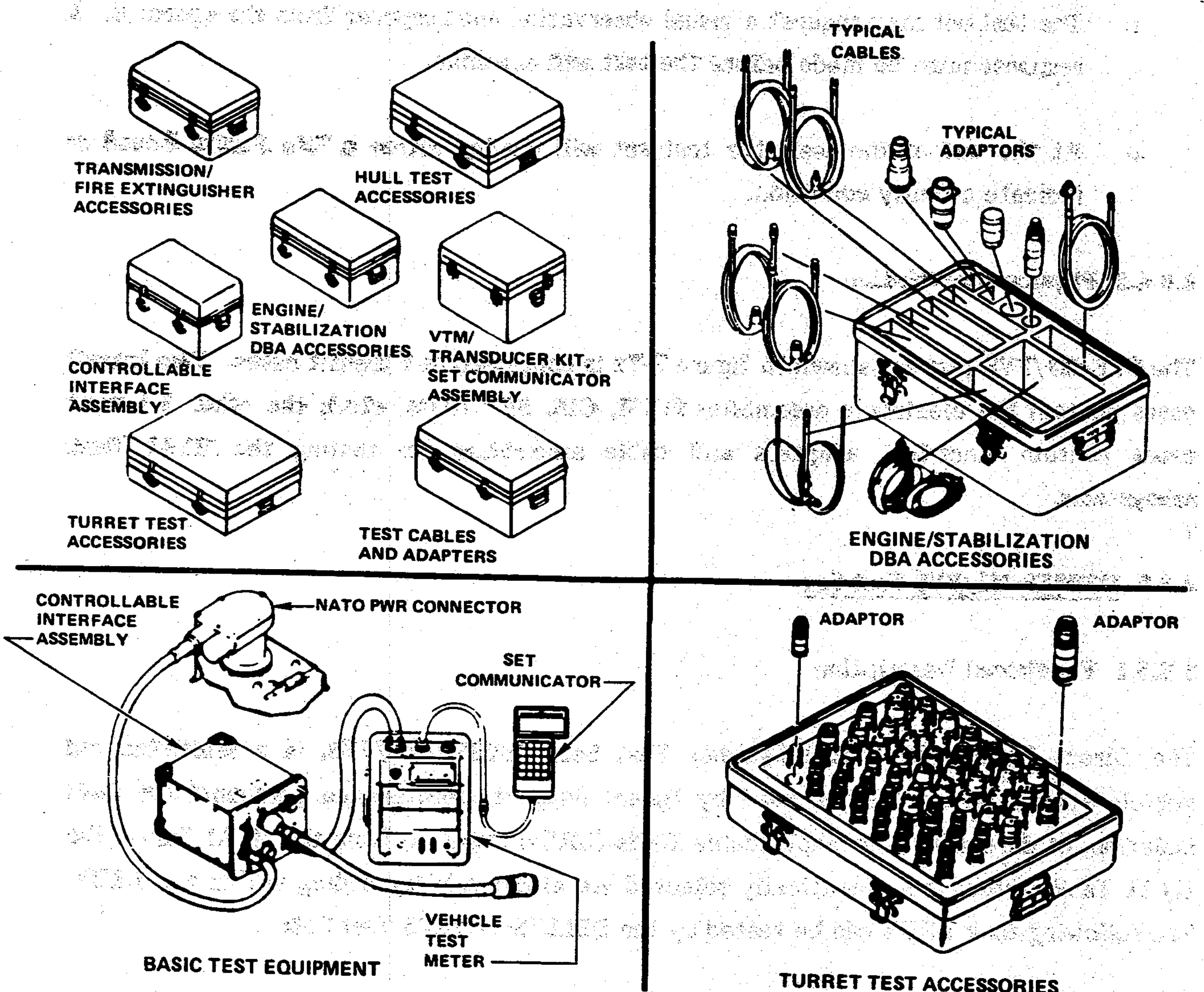


Figure 3-72. STE-M1/FVS Test Set

Temperature Control Unit (TCU)

Tank Commander's Panel (TCP)

Hull Networks Box (HNB)

The DSESTS-M1/FVS Test Set is a microcomputer controlled test device. Stored programs configured to support the M1A1 Tank System control the sequence of operation, measurement and stimulus functions, and perform the test logic to isolate faults to a replaceable module/subassembly of an LRU.

The DSESTS cable set includes all necessary cables for interconnecting each of the LRU's to be tested. The DSESTS provides power and stimuli to the LRU and measures signals and responses. The results of the measurements are compared with stored limits and determined to be acceptable or unacceptable. Unacceptable measurements result in a displayed failure message. Acceptable measurements result in allowing the test sequence to continue, or can result in the end of a test with no faults found. Where operator actions are required, stored messages are displayed on an alphanumeric display to direct the operator. Operator responses are monitored to assure that appropriate actions have been taken.

3.8.5.2 Physical Description

The physical configuration of the DSESTS-M1/FVS Test Set is shown in figure 3-73. It consists of four cases, an electronics unit, and three other cases containing cables and ancillary equipment.

The electronics unit contains all of the stimulus and measurement circuits on replaceable plug-in circuit cards. The electronics unit also includes the operator's panel which contains the controls indicators, display, and interface connectors.

An external regulated DC power supply is required that is adjustable form 18 to 30 volts and capable of supplying the DSESTS-M1/FVS Test Set with a current capability of 30 amps.

3.8.6 Thermal System Test Set

3.8.6.1 Functional Description

The Thermal System Test Set (TSTS) is a portable semi-automatic system designed for use by direct support/general support (DS/GS) level maintenance personnel for fault isolation to replaceable cards and modules of the M60 TTS and M1 Thermal Imaging System (TIS) units. The M1A1 TIS units tested are:

Power Control Unit (PCU)
Electronics Unit (EU)
Image Control Unit (ICU)
Thermal Receiver Unit (TRU)

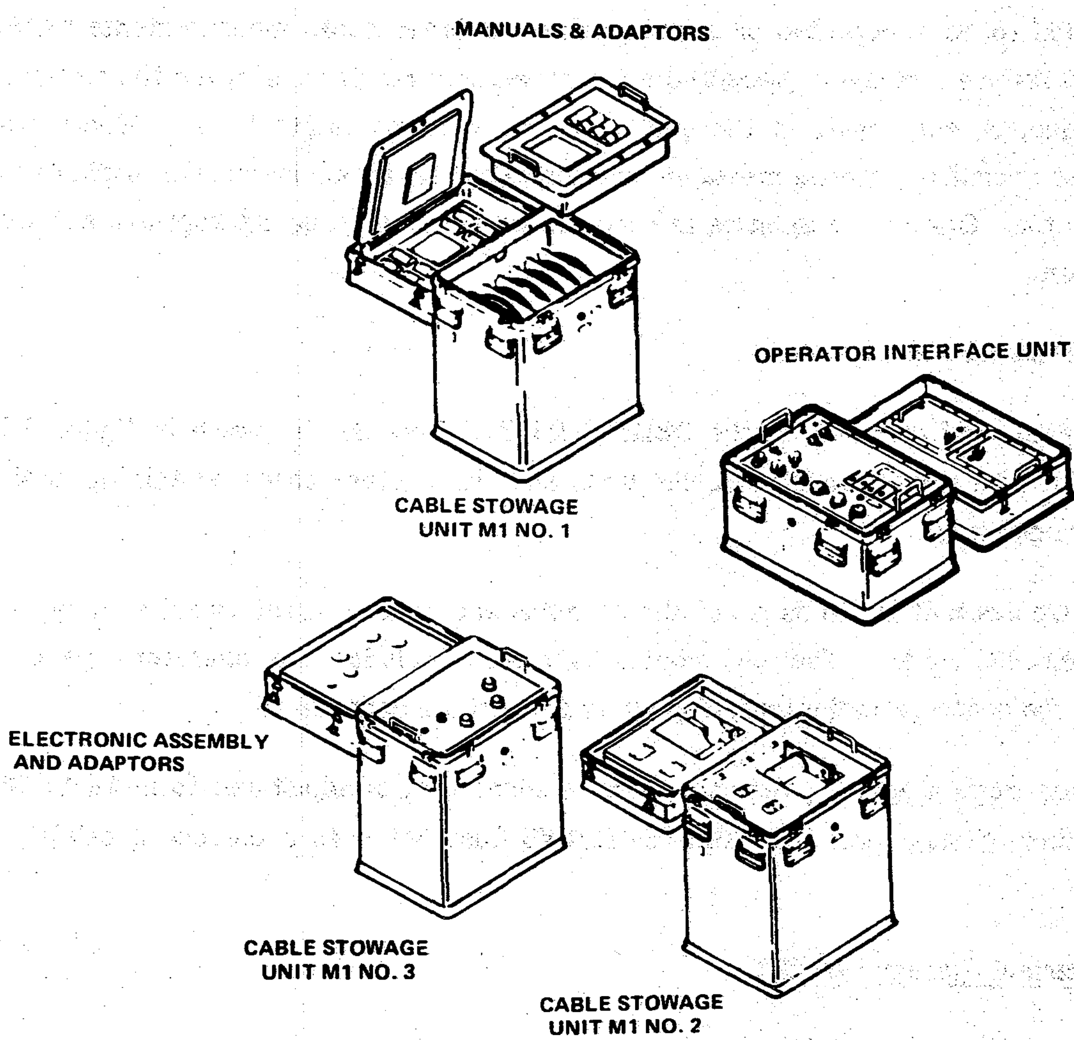


Figure 3-73. DSESTS-M1/FVS Test Set

The TSTS utilizes a microprocessor and stored program routines to control the functions of the test set. The stored program, in conjunction with operator responses, controls the following:

- sequence of testing operations
- measurements and stimulus
- display messages
- control and monitor panel functions
- performs logic necessary to fault isolate to replaceable cards and modules

The program messages to the operator are displayed on an alphanumeric display and the operator uses the controls on the TSTS front panel to provide the necessary responses.

Included in the test set is an accessory case which contains the required unique adapter tools and test cables to perform the individual unit tests. The test set also includes a holding fixture and portable collimator to perform the required diagnostic routines.

The TSTS is shown in figure 3-74.

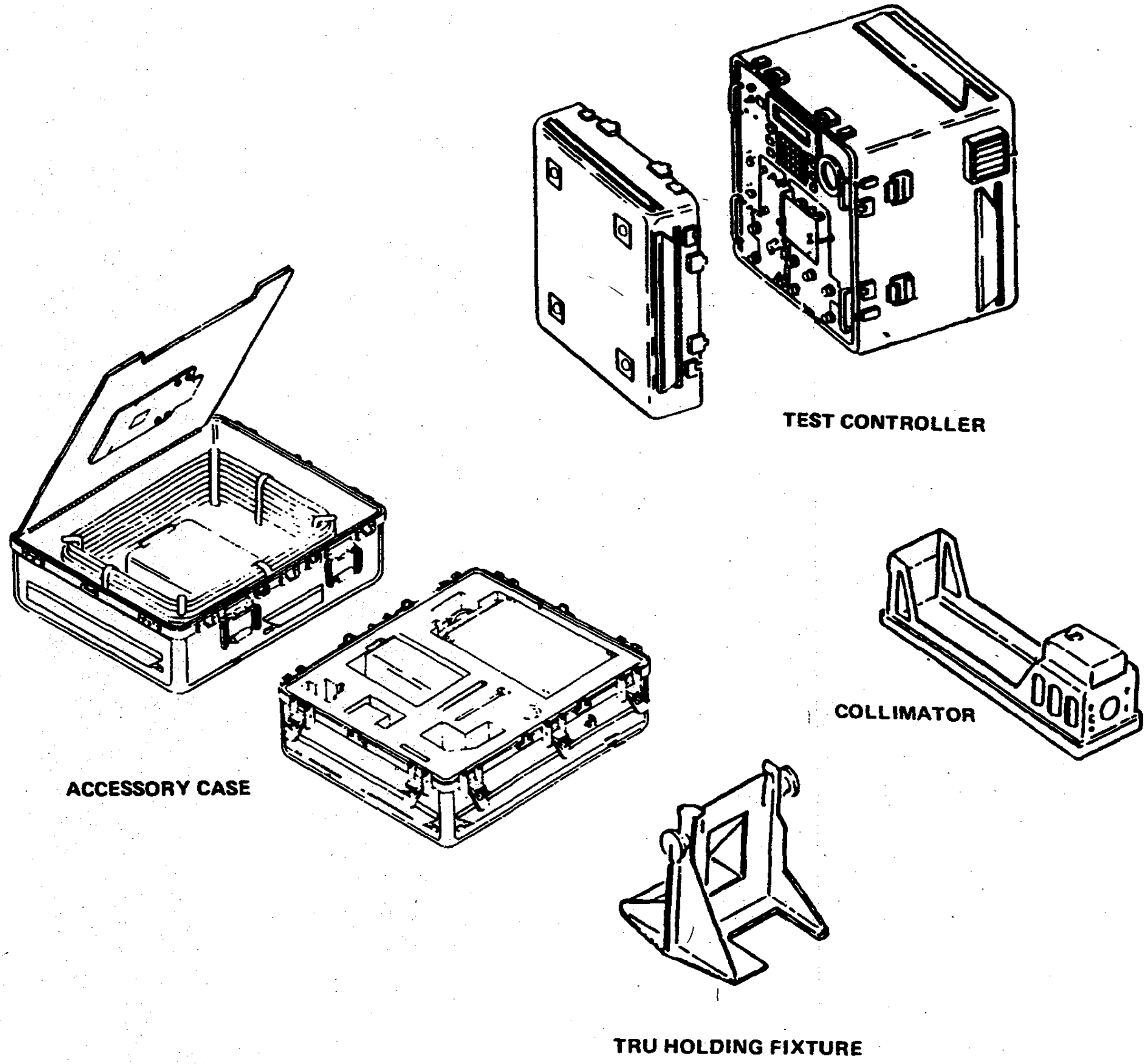


Figure 3-74. Thermal System Test Set

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