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DEPARTMENT OF THE ARMY FIELD MANUAL

LIGHT ANTIAIRCRAFT ARTILLERY (AUTOMATIC WEAPONS)

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LIGHT ANTIAIRCRAFT ARTILLERY (AUTOMATIC WEAPONS)

***This manual supersedes FM 44-2, 24 August 1950, including C 1, 26 November 1952.**

PART ONE
ORGANIZATION AND TACTICS
CHAPTER 1
INTRODUCTION

1. Purpose and Scope

This manual is for the use of battalion commanders and staff, battery commanders, platoon leaders, and fire unit leaders of AAA (AW) (antiaircraft artillery automatic weapons). It covers the organization, reconnaissance, selection, and occupation of positions, communications, observation and early warning, security, logistics, gunnery, and fire control sighting devices of antiaircraft artillery automatic weapons batteries and battalions. Part one includes battalion organization and tactics. Part two includes antiaircraft and surface gunnery techniques and fire control devices. Fundamental tactical employment principles of antiaircraft artillery automatic weapons units are contained in FM 44–1.

2. References

For a list of references containing material supplementing this manual, see appendix I.

CHAPTER 2
ORGANIZATION

Section I. MISSIONS

3. General Mission

The mission of AAA (AW) is to attack and destroy enemy targets in the air, on land, and on water. This mission is divided into air defense and surface missions. Force commanders assign missions to AAA (AW) units. A commander may decide to use all or any part of his AAA (AW) against ground or water targets while there is a threat of air attack if he considers that these targets offer a greater threat to the successful accomplishment of his mission than an air attack. Antiaircraft artillery automatic weapons are disposed and emplaced to best execute the assigned mission, air or surface defense. When practical, the weapons are sited to permit attack on targets other than those included in the assigned mission.

4. Air Defense Mission

The mission of AAA (AW) in defense against air attack is to attack all forms of enemy aircraft and missiles, to destroy them, to nullify their effectiveness, or to force them to abandon their mission. Automatic weapons are employed in the zone of interior, communications zone, and combat zone. It is the responsibility of the battalion commander in a one-battalion defense, or higher unit commander in a multiple battalion defense, to design the entire defense and designate position areas to be occupied by the fire units. A discussion of AAA (AW) defense designing is contained in FM 44–1.

5. Surface Mission

The mission of AAA (AW), when employed in defense against surface attack, is to give fire support to other arms; to neutralize or destroy targets which are most dangerous to the supported arm by providing or reinforcing field artillery fires, and by attacking and destroying targets of opportunity on land or water. Details of employment in a surface mission are covered in chapter 4.

Section II. BATTALION

6. Antiaircraft Artillery Automatic Weapons Battalion

The battalion is the basic tactical and administrative unit. It is composed of a headquarters and headquarters battery and four firing batteries. See appropriate TOE (tables of organization and equipment) for specific organization and equipment.

7. Battalion Commander

a. The battalion commander is responsible for all battalion activities. He is responsible for the tactical and technical employment of his unit and its combat effectiveness, its training, administration, discipline, supply and maintenance of equipment, and the well-being and morale of its personnel. He exercises command by making decisions and issuing orders to battery commanders, and supervises the activities of the unit by means of reports and frequent personal visits and inspections covering all phases of activity engaged in by elements of his command.

b. In accordance with assigned missions and orders of higher authority, the battalion commander will prepare and execute standing operating procedures for the unit. He must:

(1) Keep himself and his subordinates informed of friendly and enemy situations for both ground and air.

(2) Maintain communications and liaison with adjacent and supported units and insure proper functioning of those communications nets required for the tactical success of the unit.

(3) Coordinate the AAAIS (antiaircraft artillery information service) within the unit and insure its proper functioning in accordance with current instructions from higher headquarters.

(4) Make certain the commissioned officers assigned to duty as AAOO (antiaircraft artillery operations officer) are qualified for that position.

8. Battalion Staff

a. A battalion staff is provided to assist the commander in the exercise of his command, in unit training, and in forming and executing a plan for combat. The staff secures and furnishes required information, prepares details of plans and orders, transmits orders to subordinate commanders when necessary, and provides staff supervision over all activities of the battalion.

b. Figure 1 shows the organization of the AAA (AW) battalion staff. For detailed study of staff doctrine, procedures, and duties, see FM 101–5. Specific duties applicable to AAA (AW) battalion staff officers are in the following paragraphs. Common responsibilities of the head of each staff section include:

(1) Organization and supervision of the section.
(2) Training personnel in section duties.
(3) Maintaining such records, charts, or maps as required by specific duties, including preparation of appropriate portions of the unit report.
(4) Informing other staff members and battery commanders of pertinent information received.
(5) Advising the commander on technical aspects of the staff position.
(6) Serving as AAOO when required.

9. Executive Officer

The executive officer is second in command of the battalion, acting as the principal assistant and advisor to the commander. His duties correspond to those of chief of staff and/or deputy commander of a division or higher. In general, his job is to relieve the commander of detailed supervision of administration and operations, enabling the commander to devote himself to command functions. The executive officer must be prepared to assume command of the battalion at all times by keeping fully informed of the situation. His duties are to—

a. Supervise the battalion staff activities.

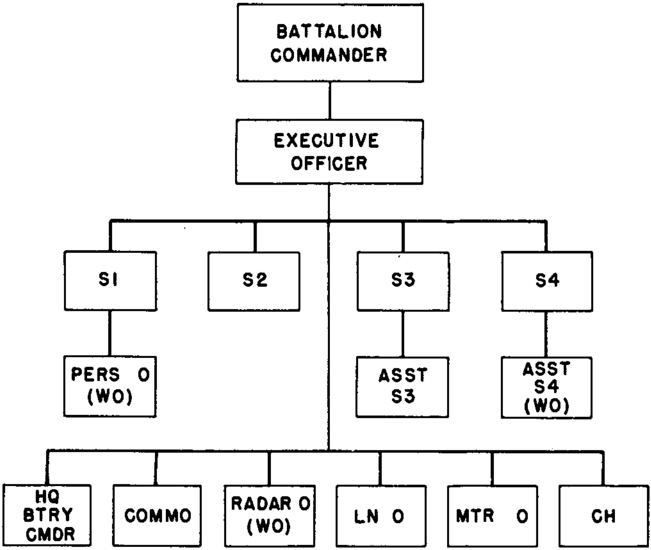

Figure 1. Organization of the battalion staff.

b. Supervise the establishment and operation of the command post.

c. Coordinate battalion security measures.

d. Supervise the compilation of required reports, such as the unit journal and command report.

e. Supervise the establishment and operation of the battalion AAOC.

f. Coordinate and supervise the displacement and movement of the unit.

g. Supervise the installation and operation of the AAAIS, and communication nets required for tactical success of the unit.

10. S1

The S1, as battalion adjutant, plans, coordinates, and supervises administrative and personnel functions of the battalion. A personnel officer is his assistant.

a. Administrative duties of the S1 are to—

(1) Process official correspondence.

(2) Supervise publication, distribution, and authentication of all orders, except combat orders.

(3) Maintain the records of the battalion.

b. Personnel duties of the S1 are to—

(1) Prepare strength records and reports.

(2) Requisition and process personnel replacements.

(3) Supervise discipline and legal activities including the processing of court-martial cases.

(4) Handle the administration of civilian employees, civil affairs, and prisoners of war.

(5) Supervise and record the classification, assignment, promotion, pay, allotments, transfers, casualties, and separation of personnel.

(6) Supervise morale activities, including postal facilities, awards and decorations, leaves and passes, recreation and exchange facilities, and religious and welfare matters.

(7) Maintain the unit journal and other records not assigned to other staff sections.

(8) Handle personal effects with the assistance of the summary court officer.

(9) Supervise administrative procedures.

(10) Handle internal arrangement of battalion headquarters.

11. S2

The S2 is the battalion intelligence officer. He collects, evaluates, interprets, and disseminates all combat information and intelligence received at battalion headquarters. In addition, his duties are to—

a. Supervise the installation and operation of the AAAIS.

b. Coordinate intelligence training.

c. Coordinate all means of gathering information pertaining to the enemy situation, both air and ground, from all sources.

d. Make sure that this information is processed, evaluated, interpreted, and disseminated reliably and efficiently.

e. Make sure that a comprehensive system of recognition and identification of friendly aircraft is established. This system must provide for maximum exploitation of visual means and proper employment of electronic means. Limitations imposed by the human element must be minimized.

f. Requisition and distribute maps.

12. S3

The S3 is the battalion operations and training officer. He has one officer assistant. The principle duties of the S3 are to—

a. Prepare plans for and supervise the organization, training, movement, and combat operation of the battalion.

b. Assist in the preparation and issuance of operations orders and instructions.

c. Assist in the establishment and operation of the AAOC.

d. Keep up-to-date information of the operating status of materiel, training, weapon locations, and missions.

e. Make sure that all commissioned and enlisted personnel assigned duties in the AAOC are competent and well trained.

f. Make sure that the means of tactical battalion control are adequate and that—

(1) A complete but brief SOP (standing operating procedure) for engagement control and target selection is provided for each fire unit leader and that fire unit personnel are well versed in its contents.

(2) A list of instructions for implementation of the fire unit SOP is composed for the use of the AAOO.

g. Make certain that means of communication provided for the control of battalion elements is reliable, rapid, and within tactical requirements.

h. Coordinate liaison activity, TIE (troop information and education) functions, use of training facilities, and the analysis of defenses.

13. S4

The S4 is the battalion supply officer and supervises the operation of supply, evacuation, transportation, and maintenance. He has one warrant officer assistant. Principle duties of the S4 are to—

a. Requisition and distribute all supplies.

b. Supervise food service.

c. Coordinate the planning, supervision, and allocation of ammunition supply operations and critical supplies with the S3.

d. Coordinate administrative orders and motor movements with S3.

e. Keep current information for the battalion commander on the status of supply, property accounting procedures and records, and organizational maintenance of equipment.

f. Collect and process salvage.

14. Communication Officer

The battalion communication officer, under supervision of the S3, supervises the installation and operation of the communication nets that are needed to meet the tactical and administrative requirements of the battalion. Specific duties are to—

a. Organize and operate the battalion communication center.

b. Advise the battalion commander and staff on all matters of communications, to include communication training and the status of communication supply and maintenance.

c. Maintain communication with the staff of the next higher, lower, adjacent, and supported units as directed by higher headquarters.

d. Install and maintain those means of communications used in the operation of the AAOC and AAAIS.

15. Motor Officer

The motor officer, under S4 supervision, advises the commander and staff on motor maintenance and transportation. He supervises the operation and maintenance of battalion wheel and track vehicles and trains his personnel.

16. Chaplain

The chaplain advises the commander and staff on moral and religious matters in the battalion. He conducts religious services, advises personnel on spiritual matters, ministers to sick and wounded, and corresponds with relatives of sick, wounded, and deceased personnel. He does not perform operational duties such as AAOO.

17. Liaison Officer

The liaison officer is the personal representative of the battalion commander, acting as a link between the battalion headquarters and the headquarters to which he reports. Functioning under the supervision of the S3, he makes sure that the tactics, techniques, and employment of the unit he represents are understood by the commander of the organization to which he is detailed.

18. Radar Warrant Officer

The radar warrant officer is a special staff officer and normally works under the supervision of the S2. The duties of the radar officer are to—

a. Advise the commander and staff on the status of radar equipment issued to the battalion.

b. Supervise movement and siting of the surveillance radar.

c. Supervise operation and maintenance of radar equipment.

d. Supervise preparation of cover and clutter diagrams.

e. Assist in the establishment of the AAAIS and air warning nets.

Section III. BATTERY

19. Headquarters Battery

Headquarters battery furnishes the necessary personnel and equipment to assist the battalion in functions of command, control, reconnaissance, communication, intelligence, logistics, and administration. See appropriate TOE for organization.

20. Headquarters Battery Commander

The headquarters battery commander commands headquarters battery and acts as headquarters commandant. He is responsible for the supply, mess, quarters, pay, conduct, training, health, and morale of his unit personnel. As headquarters commandant, he is responsible for:

a. Organization and security of the battalion command post.

b. Physical movement of battalion headquarters.

c. Supervision of mess and transportation facilities for battalion headquarters.

21. Automatic Weapons Battery

The automatic weapons battery consists of a battery headquarters and two platoons of eight fire units each. An automatic weapons fire unit is considered to be one weapons mount. The platoon has four multiple gun motor carriage M16A1's and four 40-mm gun motor carriage M42's in self-propelled units; four multiple machinegun trailer mount M55's plus four 40-mm gun on carriage M2A3's in mobile units. The airborne automatic weapons battery consists of a battery headquarters and three platoons of six fire units each. The airborne platoon has four M55's plus two M42's.

22. Battery Commander

The AAA (AW) battery commander is responsible for all activities of the battery, including administration, training, and tactical employment. His specific duties are to—

a. Accomplish the combat mission of the battery.

b. Carry out training schedules, supervise actual instruction, and maintain proper discipline.

c. Keep battery records, supply and maintain clothing and equipment, and supervise food service.

23. Battery Executive Officer

The battery executive officer assists and advises the battery commander, and makes sure that his policies are carried out. He is second in command of the battery and normally acts as battery liaison officer in surface or AA (antiaircraft) missions with infantry, armor, or field artillery units.

24. Platoon Leaders and Assistant Platoon Leaders

These officers are responsible to the battery commander for training personnel of their platoon, the tactical employment of the platoon, and the administration of the platoon in the field.

25. Fire Unit Leader

The fire unit leader is directly subordinate to the platoon leader. He supervises target selection and exercises engagement control of his fire unit. His responsibilities and functions are to—

a. Train his crew in service of the piece.

b. Train his crew in the SOP for engagement control and target selection.

c. Understand the application of such basic tactical principles as:

(1) The value of primary and secondary sectors of fire.

(2) The necessity for overlapping adjacent primary sectors of fire.

(3) The greater threat to the vital area of an incoming target than an outgoing target in the primary sector of fire.

(4) The rule for engaging an incoming target in the secondary sector before an outgoing target in the primary sector of fire.

(5) The necessity for engaging a target at maximum effective range to produce maximum effective fire.

(6) The importance of smooth and rapid target transfer during a multiple target raid.

(7) The importance of maximum use of visual aircraft recognition means because of limitations of available fire control equipment.

d. Inform his crew of the limited engagement time available and the importance of communications.

CHAPTER 3
CHARACTERISTICS OF EQUIPMENT

26. General

a. Antiaircraft artillery automatic weapons use a projectile which must hit the enemy aircraft, or surface target, to be effective. The 40-mm gun uses a shell with a supersensitive fuze which bursts on contact. If no contact is made as the tracer burns out, the relay ignition charge is ignited detonating the bursting charge of the shell. The caliber .50 machinegun uses API (armor-piercing incendiary) ammunition with and without tracer.

b. Automatic weapons have a flexibility that enables them to track aircraft at a high angular rate and shift quickly from one target to another. These factors, plus a high rate of fire, make automatic weapons highly effective against low-flying aircraft at short ranges.

c. The M42 and M16A1, self-propelled AAA (AW), because of their greater mobility, are desirable for use with combat forces.

27. Ammunition

a. *Types*. The principal types of ammunition for the caliber .50 machinegun are API and API–T (armor-piercing incendiary tracer). The 40-mm gun uses high explosive and armor-piercing tracer shot. The tracer element of the caliber .50 ammunition burns out at ranges of 1,850 or 2,450 yards, depending on the type. The 40-mm high explosive shell destroys itself at the tracer burn-out point varying from 3,500 to 5,500 yards, depending on the type.

b. Uses. The various types of ammunition are used as follows:

(1) Caliber .50 API–T and API ammunition and 40-mm high explosive shells are used against personnel and light materiel.

(2) Caliber .50 API, API–T, and 40-mm armor-piercing ammunition are used against lightly armored vehicles, concrete shelters, and similar targets.

(3) The tracer element of the caliber .50 and 40-mm ammunition are used primarily for observation of fire.

(4) All types of automatic weapons ammunition may be employed against aerial targets.

28. Range Capabilities

a. Extreme Deterrent Range. The extreme deterrent range is the tracer burn-out range of automatic weapons projectiles. At this range, the fire is inaccurate but, if delivered with maximum density, may cause enemy aircraft to take evasive action, break formation, and even abandon their mission. Extreme deterrent ranges of automatic weapons are:

(1) Caliber .50 machineguns: 1,800 to 2,450 yards.

(2) 40-mm gun: 3,500 to 5,500 yards.

b. Effective Hitting Range. Effective hitting range is the maximum distance within which hits may be expected. It depends on tracer observation, but in addition, is determined by the type of sighting device, lead tolerance, angle of approach, and the average state of training of personnel. The average effective hitting ranges are:

(1) Caliber .50 machinegun: 800 yards.

(2) 40-mm gun: 1,800 yards.

c. Minimum Midpoint Tracking Range. This is the shortest midpoint range at which the weapon can track a target. It depends on target speed and the maximum tracking rate of the gun mount. The caliber .50 machinegun turret mount can track a 600-mile-per-hour target at a midpoint range of 300 yards. The M42 can track a 600-mile-per-hour target at approximately 420 yards midpoint range.

29. Weapons

a. 40-mm Gun. The 40-mm gun may be either fully automatic or semiautomatic; it can deliver short bursts at a rate of 120 rounds per minute. It is air-cooled and, if fired at maximum rate, will overheat after about 100 rounds are fired. Firing must be suspended and the barrel changed when it is overheated. The horizontal range for antiaircraft tactical planning is 1,800 yards.

b. Caliber .50 Machinegun. The individual caliber .50 machinegun fires at a rate of 400 to 600 rounds per minute. Although the effective range is dependent upon the gunner's depth perception and training, a horizontal range of 800 yards is used for tactical planning purposes. The standard mount for the caliber .50 machinegun is an electrically operated, quadruple gun mount. These quadruple mounts can be traversed and elevated at rates of 80° per second by a single operator.

30. Self-Propelled Carriages

a. The twin 40-mm gun motor carriage M42 (fig. 2) has two 40-mm guns mounted coaxially on a full track vehicle.

b. The multiple gun motor carriage M16A1 (fig. 3) is a quadruple machinegun mount (M45) installed in a half track vehicle.

31. Towed Mounts and Carriages

a. 40-mm Gun on Carriage M2A3 (fig. 4). The 40-mm gun on carriage M2A3 is used in mobile units. The time required to emplace the carriage from traveling position and commence firing (utilizing the primary means of on-carriage fire control) is 1 to 2 minutes.

b. Multiple Machinegun Trailer Mount M55 (fig. 5). The multiple machinegun trailer mount is used in mobile and airborne units. The mount may be towed for short distances but is generally transported in a 2½-ton truck, or loaded without disassembly in conventional type troop carriers. The mount must be emplaced before firing, the time for emplacement requiring 1 to 2 minutes. The turret in the trailer mount is the M45.

32. Fire Control Devices

a. 40-mm Speed Ring Sights (fig. 32). The 40-mm gun has two metal speed ring sights used as secondary means of fire control.

b. M18 Reflex Speed Ring Sight (fig. 33). The M45 caliber .50 multiple machinegun utilizes the M18 speed ring sight as the only means of fire control.

c. Computing Sights M38 and M19A1 (figs. 43 and 44). The computing sight is the primary means of fire control on the 40-mm gun.

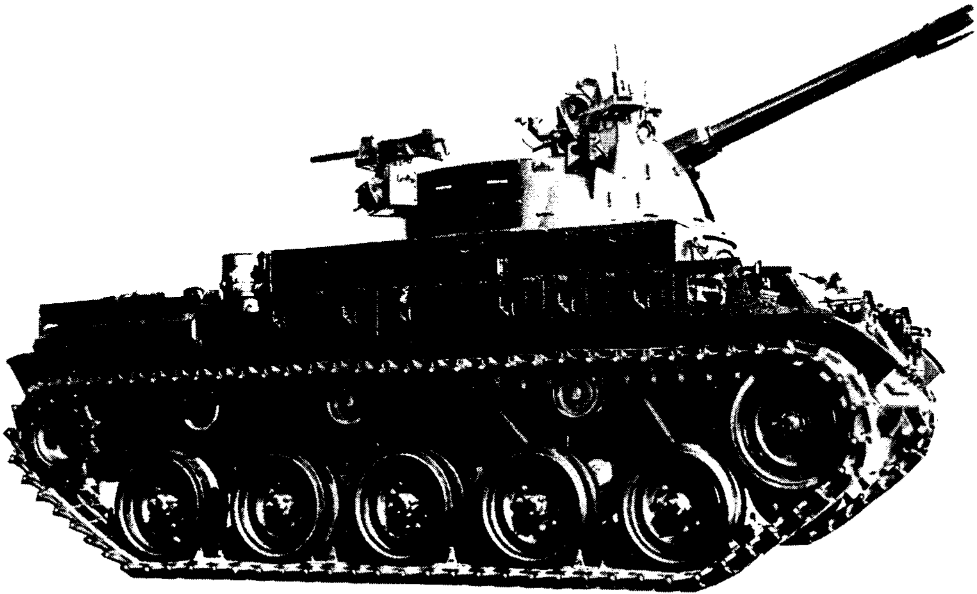

Figure 2. 40-mm gun motor carriage M42.

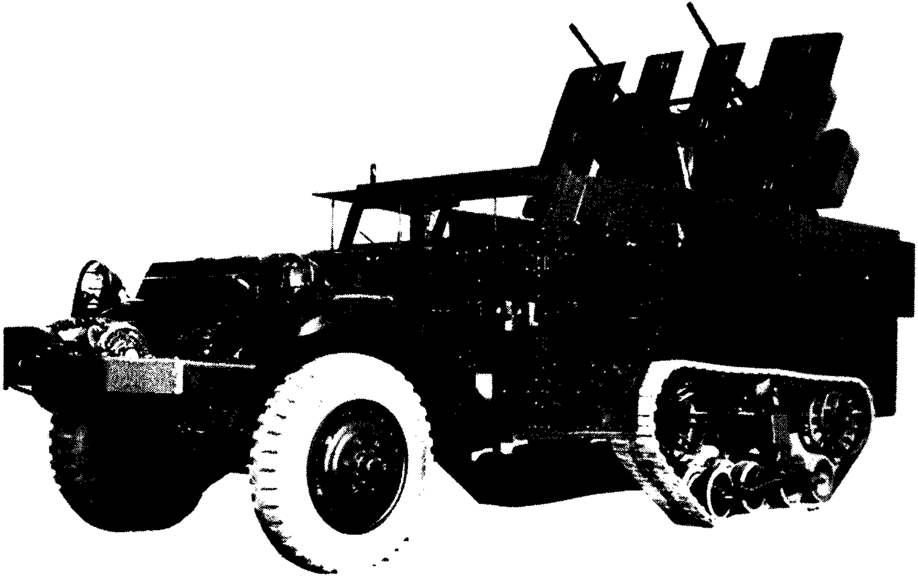

Figure 3. Multiple gun motor carriage M16A1.

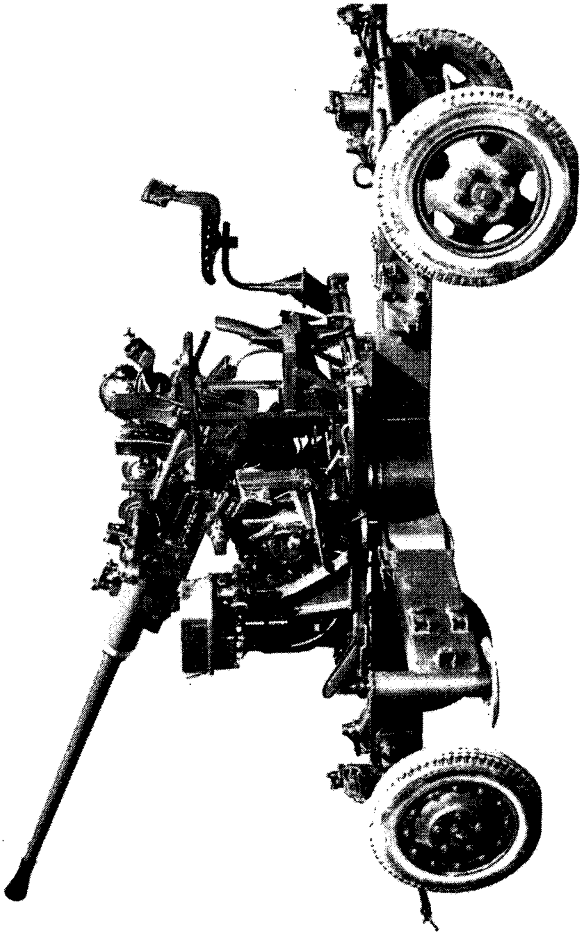

Figure 4. 40-mm gun on carriage M2A3.

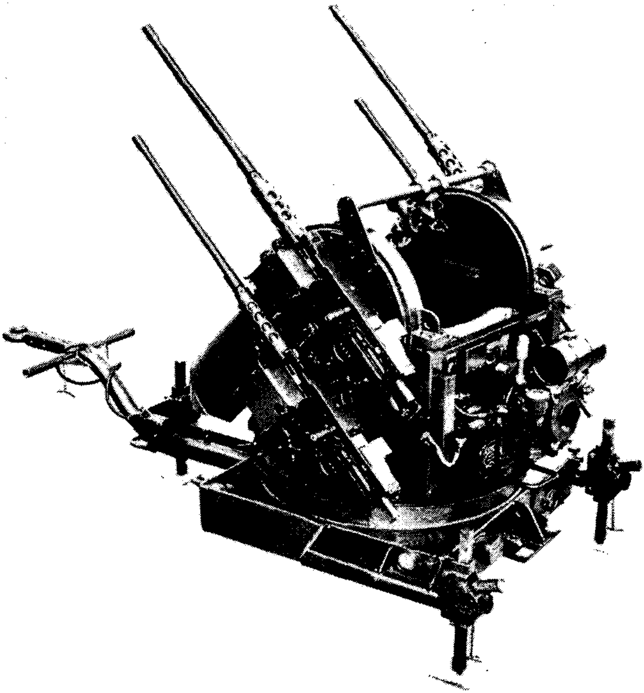

Figure 5. Multiple machinegun trailer mount M55.

CHAPTER 4

RECONNAISSANCE, SELECTION, AND OCCUPATION OF POSITION

Section I. ANTIAIRCRAFT DEFENSE

33. General

Since the AAA (AW) battalion may be given a variety of missions, for example, air defense, surface, or modifications of these two missions, it is necessary to develop separate procedures for reconnaissance, selection, and occupation of positions to accomplish each type of mission.

34. Reconnaissance

a. General. The purpose of reconnaissance is to obtain accurate information concerning terrain on which personnel, vehicles, and weapons will be operating. The two general classifications of reconnaissance are route and position. Position reconnaissance establishes actual positions on the ground for location of weapons, vehicles, and command posts. Route reconnaissance is the selection of routes suitable for moving personnel and equipment to and from selected positions.

b. Types of Reconnaissance.

(1) *Map reconnaissance.* A map reconnaissance is generally used as a basis for planning a ground or aerial reconnaissance. Higher headquarters normally makes this type of

reconnaissance. Lower headquarters, if time is available, makes a more detailed ground reconnaissance. In a rapidly moving situation, however, there may be little time available for reconnaissance other than by map.

(2) *Aerial reconnaissance.* This type of reconnaissance may be used preceding, simultaneously with, or in place of, a ground reconnaissance. Aerial reconnaissance is speedier than ground reconnaissance but it does not provide as detailed information as ground reconnaissance.

(3) *Ground reconnaissance.* There is no substitute for ground reconnaissance, which provides a detailed examination of the terrain.

c. Time Available. Since time available for reconnaissance may often be very limited, each commander must anticipate possible displacements and perform a continuous progressive reconnaissance and study of the terrain. Whenever possible, commanders must allow enough time for subordinates to complete their reconnaissance during daylight hours.

d. Battalion Reconnaissance. Since AAA (AW) batteries and platoons often operate in fluid situations and are separated by considerable distances, the battalion commander can rarely perform a ground reconnaissance of all fire unit positions. When time is limited, the battalion commander will decentralize reconnaissance to subordinates and will later consolidate and organize as time permits. When time does permit, however, the following steps, subject to variations as the situation demands, are performed. He—

(1) Makes a map reconnaissance to locate all elements.

(2) Decides the exact time for start of troop movements.

(3) Decides when and how to make ground reconnaissance and who will accompany him.

(4) Issues warning orders to subordinates covering—

(*a*) Enemy and friendly situation.

(*b*) Troop movements desired.

(*c*) Time and place for issue of further orders.

(*d*) Probable route of reconnaissance party.

(5) Performs reconnaissance, and verifies—

(*a*) Sites for AAAIS surveillance radar and visual observer posts.

(*b*) Location of battalion AAOC.

(*c*) Position of headquarters battery service elements.

(*d*) Routes to positions.

(*e*) The location of each battery headquarters and as many fire unit positions as time will allow.

(6) Returns to assembly point and issues orders to subordinates for occupation of positions.

e. Battery Reconnaissance.

(1) *Adequate time.* If the battalion commander makes a complete reconnaissance of all fire unit positions, the battery commander will be responsible for the details of occupation and make arrangements for having his fire units directed to positions. If, however,

the battalion commander does not make a ground reconnaissance, the battery commander will make a ground reconnaissance based on the battalion commander's map reconnaissance. This will determine—

(*a*) Routes to all positions.

(*b*) Position of each weapon.

(*c*) Alternate positions and dummy positions.

(*d*) Exact location of battery command post, bivouac area, and truck park.

(*e*) Sectors of fire for each fire unit.

(2) *Procedure.* Before departing, the battery commander briefs his executive officer on orders of the battalion commander. If the battery commander is to return before the elements of the battery start moving, the executive officer is informed of the probable time the battery commander will return from the reconnaissance. If elements of the battery start moving before the battery commander completes his reconnaissance, the executive is given the time of movement from the assembly area, the route, and special instructions concerning the march.

(3) *Limited time.* The battery commander may have his firing units so widely separated that time is not available to make a ground reconnaissance of all his unit positions. In this case, the platoon leaders and NCO (noncommissioned officers) must perform the reconnaissance. The battery commander will consolidate the unit positions if and when time is available.

f. Platoon Reconnaissance. When enough time is available, the platoon leaders accompany the battery commander on reconnaissance to coordinate sectors of fire. When time is limited, the platoon leaders with the fire unit leaders perform the reconnaissance and select positions in accordance with orders from the battery commander. In fast-moving situations, the platoon leader may designate the positions and general layout of the fire units, while the actual ground reconnaissance is made by the fire unit leaders just prior to moving into their positions.

35. Selection and Occupation

a. Sectors of Fire and Observation.

(1) Each automatic weapons fire unit is assigned a primary and secondary sector of fire. All fire unit crews maintain constant vigilance in their primary sectors of fire, regardless of the sector in which the weapons are actually engaged.

(2) Since target selection and engagement control depend upon visual means, the sites which are selected for the weapons must provide for maximum observation and un obstructed sectors of fire. Adjacent 40-mm fire units must be sited within 100 to 900 yards of each other. Caliber .50 weapons are sited within mutual support distances of 100 to 400 yards. The limitation imposed by tracer observation requires that fire units be sited at least 100 yards apart. To provide the required concentration of fire against aerial targets and insure cover-

age of the dead area of adjacent weapons, 40-mm fire units must be sited not farther than 900 yards apart.

b. Level Ground. The ground for emplacing automatic weapons should be within 2° of level. If necessary, the selected location should be leveled within tolerance using tools available.

c. Cover. Immediately after a position has been selected and occupied and the fire unit is prepared to engage the enemy, cover is provided for protection of personnel and materiel. Fox holes or slit trenches are dug by all personnel.

d. Occupation. Actual occupation of a position is directed and supervised by the fire unit leader. Timely arrival and prompt readiness for fire are the primary considerations. Weapons are emplaced first and then, as time permits, the positions are improved by fortification and construction of alternate positions. Dummy positions are constructed as directed by higher headquarters.

Section II. SURFACE MISSION

36. General

a. The methods outlined in this section apply to all types of surface employment, whether in close support of infantry in offense or defense, in defense against mechanized, airborne, guerilla, or infiltration attacks, or in engagement of naval targets.

b. Since infantry and armored divisions have an organic AAA (AW) battalion assigned, the division commander may designate the mission of this battalion as that of close support of infantry elements, in part or in whole. This AAA (AW) battalion contains self-propelled weapons, and as such is capable of diversified uses in the close support role. Although the towed 40-mm gun may be used in a surface role, it is limited by its lack of mobility and the length of time needed to emplace it.

37. Command, Control, and Coordination

a. When AAA (AW) units are assigned surface missions, they are normally attached to supported units. Antiaircraft artillery automatic weapons commanders serve as special staff officers of the commander of the supported unit and advise these commanders on the employment of AAA (AW). Antiaircraft artillery automatic weapons platoon command posts are located at or near the command post of the supported unit. The normal role of automatic weapons battery and platoon commanders is to direct the operations of their units. Battery and platoon executives serve as liaison officers with supported units. Liaison is also established with each committed rifle company. The AAA (AW) unit commander provides a noncommissioned officer assisted by a radio operator to advise the rifle company commander of the capabilities of AAA (AW) and to act as a forward observer.

b. Some of the automatic weapons attached for close support are given interdiction, harassing, or neutralization fire missions. Other automatic weapons may augment the infantry heavy weapons by overhead fire, and fire through gaps in the friendly lines. Regardless of what mission is given, the support fires must be carefully prepared and coordinated with the plans of the attack or defense of the infantry or armor unit commander.

38. Reconnaissance and Plans

a. The automatic weapons platoon leader is responsible for performing the ground reconnaissance in the surface mission. After being briefed by the infantry battalion commander as to the general plan of action, the amount of fire support desired, the exact location of friendly units and of known and probable enemy targets such as direct fire weapons and observation posts, and after studying the map carefully, the platoon leader makes a personal ground reconnaissance, attempting to gain the following information:

(1) Primary and secondary firing positions for each weapon.

(2) Routes to primary and alternate positions.

(3) Location of new firing positions to be used in case of lateral, forward, or rear displacements.

(4) Routes to displacement positions.

(5) Location of ammunition vehicle parks and routes of supply.

(6) Platoon observation posts.

(7) Positions for reinforcement of the main battle position in the event of an envelopment or penetration.

(8) Key points in the battalion area essential to the defense of the area.

(9) Likely avenues of approach of hostile forces.

b. The automatic weapons employment plan for support of infantry or armor will be coordinated with the infantry or armor commander and should include:

(1) Initial positions from which supporting fires are to be delivered. Positions will be in

the same general area with the organic infantry support weapons, as far forward as is consistent with the tactical situation, and with adequate cover.

(2) Plans and routes of displacement.

(*a*) Weapons will be displaced by echelon, with one-half the weapons in each echelon, if possible.

(*b*) Select routes affording the most rapid displacement, in order to supply continuous fire support.

(3) Ammunition supply points and protected routes.

(*a*) Estimate the amount of ammunition needed at the initial position, and dump that amount on the ground and replenish supplies so that weapons may displace with full basic loads.

(*b*) Select covered ammunition supply routes and instruct ammunition truck drivers on ammunition resupply procedure.

39. Selection and Occupation of Positions

a. The principal factor affecting the selection of positions in a surface role is complete integration with the supported unit's Fire Support Plan. Positions selected for a surface role should—

(1) Assist in the protection of vital terrain features.

(2) Retain essential observation to front and flanks.

(3) Deny the enemy close observation into the battle position.

(4) Locate positions so as not to interfere with fields of fire of weapons located in the rear.
(5) Take maximum advantage of natural cover and concealment.
(6) Site caliber .50 weapons within 1,000 yards of possible target and 40-mm weapons within 1,500 yards of possible target.
(7) Provide mutual support with infantry weapons and have safety zones to protect against firing into friendly positions.
(8) For naval targets, be as close to water level as possible to take advantage of the flat trajectory.

b. When reconnaissance and selection of positions has been accomplished and the plan of action approved by the infantry or armor commander, the automatic weapons are moved to the selected positions. This move must be coordinated with supported units so that motor columns will not interfere with foot troop or tank movements. The move should be made at night, if possible, but in any case, with maximum cover and concealment.

CHAPTER 5
COMMUNICATIONS

40. General

Antiaircraft artillery automatic weapons communications include all means employed to transmit information, intelligence, commands, orders of an operational control nature, and the means to establish liaison with other units. Due to the importance of communication to effective operation, every person involved must be thoroughly grounded in communication operation and maintenance. This is especially true in the case of the AAA (AW) units which are sometimes widely dispersed or isolated. Primary and alternate means of communication must be provided and available for immediate use by all elements of the command. The basic means of communication available to the automatic weapons units include radio, wire, and messenger. Wire is considered to be the more desirable means of communication due to its greater degree of dependability. Maximum use should be made of this means during static situations. Frequent movement and wide dispersion will often dictate the use of radio as the means of communication to be employed. The use of radio in the initial stages of an operation, in rapidly moving situations, and in amphibious operations will be essential. In many situations, wire and radio will be integrated.

41. Radio

a. The capabilities and limitations of radio equipment must be thoroughly understood by all antiaircraft artillery officers and considered by a commander when plans for radio communications are made.

(1) *Capabilities.*

(*a*) Radio sets are readily portable, may be placed in operation quickly, and may be operated from moving vehicles.

(*b*) No physical circuit is required between stations.

(*c*) Radio is a readily available means of long range communication.

(2) *Limitations.*

(*a*) Radio equipment is complex and fragile. It requires constant maintenance and intelligent care.

(*b*) Operating and maintenance personnel requires specialized individual training.

(*c*) Radio messages are easily intercepted by the enemy. Necessary cryptography delays transmission.

(*d*) Radio is subject to enemy jamming and affords the enemy means of locating transmitters, and thereby, command posts and other installations.

b. In radio nets which supplement wire nets, operators listen on assigned frequencies and do not transmit unless instructed to do so. In other radio nets, operation is normally continuous unless otherwise prescribed.

42. Wire

Wire communication equipment provided by TOE is sufficient to install essential command lines between command posts. Additional wire to install other wire nets must be drawn from the appropriate signal supply agency when required. The extent to which wire communication is installed is governed by the tactical mission of the unit. The wire communication net of a unit employed in a static situation should be as complete and extensive as time and material permit. The wire communication net of a unit employed in a moving situation, where frequent changes of position are involved, will be limited.

a. Capabilities.

(1) Wire is flexible, reliable, and less subject to mechanical and electronic failure than radio.

(2) Wire requires a somewhat lesser degree of technical skill to install and maintain than radio.

(3) Wire communications are less easily intercepted than radio.

b. Limitations.

(1) Wire requires considerable time, labor, material, and equipment to install, operate, and maintain.

(2) Wire is subject to failure due to vulnerability of long wire lines to bombing, artillery fire, enemy patrols, and damage by vehicles.

43. Radiotelephone Procedure

a. Radiotelephone procedure is covered in ACP 125. All officers and enlisted men should be thoroughly familiar with proper radiotelephone procedure and comply strictly with instructions contained in that publication.

b. Unnecessary and improper transmissions must be avoided in order to prevent the enemy from obtaining information which may reveal the tactical disposition, strength, or movement of friendly forces. Effective transmission security requires constant supervision by the commander and a high state of training on the part of personnel using communication nets.

44. Communication Nets, General

Communication nets required for an AAA (AW) defense include the following:

a. Early Warning Net. This is a one-way wire or radio net (or both) between the AA teller (a member of the AA liaison party) in the Air Force Agency and the early warning plotter at the AAOC. In the field army, the primary AAOC in the area usually establishes this net.

b. Air Force Liaison Net. This is a two-way wire or radio net (or both) which connects the AA liaison officer in the Air Force Agency with the AA defense commander's representative in the AAOC.

c. Observation Post Net. This is the net established for the transmission of information from the AAA visual observation posts to the elements of the AA defense. Due to the complexity of this net, it is rarely practical to use wire. This is a two-way net between the observation posts and the NCS (net control station) at the AAOC and a one-way net between the observation posts and all other elements of the defense.

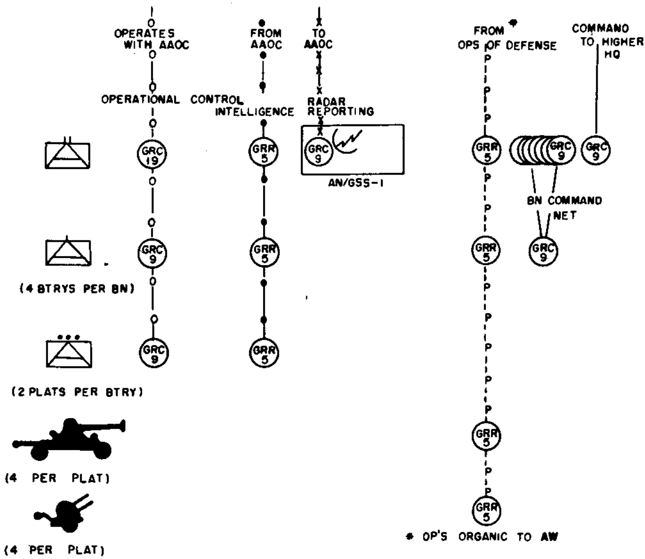

Figure 6. AAA bn (AW) (Mbl), radio nets under senior AAOC.

d. Radar Reporting Net. This is a two-way wire or radio net (or both) over which radars operating in a surveillance role within the AA defense transmit data to the AAOC.

e. Intelligence Net. This is a one-way wire or radio net (or both) over which the AAOC disseminates intelligence to the elements of the defense and other interested agencies.

f. Operational Control Net. This is a two-way wire or radio net (or both) over which the AA defense commander, or his representative from the AAOC, exercises operational control over the elements of the AA defense.

g. Command Net. This is a two-way wire or radio net (or both) over which all elements of command for which other nets are not established, including administration, are transmitted. This net is normally established from the administrative headquarters of the AA commander and not from the AAOC.

45. Radio Nets

a. Mobile Battalion, Under Senior AAOC (fig. 6).

(1) *Higher headquarters command net (AM).* The battalion operates a radio set in the AM (amplitude modulated) command net of the next higher headquarters. This net may be a voice or CW (continuous wave) net and is used for command and administrative purposes. This station operates on a frequency assigned by the higher headquarters concerned.

(2) *Battalion command net (AM).* The battalion command net includes a station at the battalion headquarters and one at each of the firing batteries. The radio at the battalion headquarters is the NCS for this net.

(3) *Intelligence net (AM).* The battalion operations center, each firing battery, and each automatic weapons platoon operate a radio receiver, AN/GRR–5, in this net.

(4) *Radar reporting net (AM).* The battalion surveillance radar is connected to the senior AAOC by a two-way radio over which information concerning radar pick-ups is transmitted to the AAOC and over which the AAOC passes special instructions to the surveillance radars.

(5) *Observation post net (AM).* The battalion operations center, each of the firing batteries, and each fire unit operate a radio receiver, AN/GRR–5, in this net to receive OP information direct from the OP.

(6) *Operational control net (AM).* The battalion operations center, each firing battery, and each of the automatic weapons platoons operate a two-way radio in this net providing direct communications between these elements and the AAOC.

b. Self-propelled Battalion, Under Senior AAOC (fig. 7).

(1) *Higher headquarters command net (AM).*

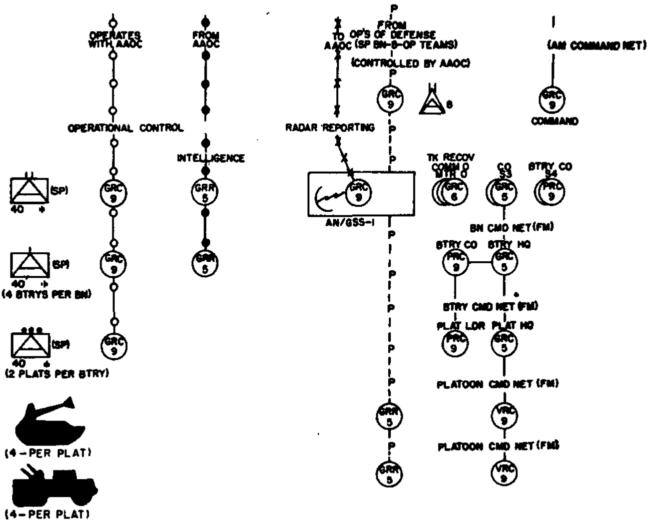

Figure 7. Self-propelled battalion antiaircraft mission, under senior AAOC.

The battalion operates a radio set in the command net of the next higher headquarters. This net may be a voice or CW net and is used for command and administrative purposes. This station operates on a frequency assigned by the higher headquarters concerned.

(2) *Battalion command net (FM).* The FM (frequency modulated) battalion command net includes at least one station at the battalion headquarters and one at each of the firing batteries. This net may include various staff officers of the battalion.

(3) *Battery command net (FM).* The battery command net consists of at least one station at the battery headquarters and one at each automatic weapons platoon headquarters.

(4) *Platoon command net (FM).* The platoon command net consists of a radio set at the platoon headquarters and one at each fire unit. (When available frequencies do not permit operation of separate platoon command nets, these nets may be combined with the battery command net and all operate on the same frequency.)

(5) *Intelligence net (AM).* The battalion operations center and each firing battery operate a radio receiver in this net.

(6) *Radar reporting net (AM).* The battalion surveillance radar is connected to the senior AAOC by a two-way radio over which information concerning pick-ups is transmitted to the AAOC and over which the

AAOC passes special instructions, as necessary to the surveillance radar.

(7) *Observation post net* (*AM*). The battalion operations center and each fire unit operate a radio receiver in this net to receive OP information direct from the OP

(8) *Operational control net* (*AM*). The battalion operations center, each firing battery, and each automatic weapons platoon headquarters operate a two-way radio in this net providing direct communication between these elements and the AAOC.

c. Divisional-Antiaircraft Artillery Automatic Weapons Battalion. The FM radio equipment of the AA (AW) battalion organic to the division will be

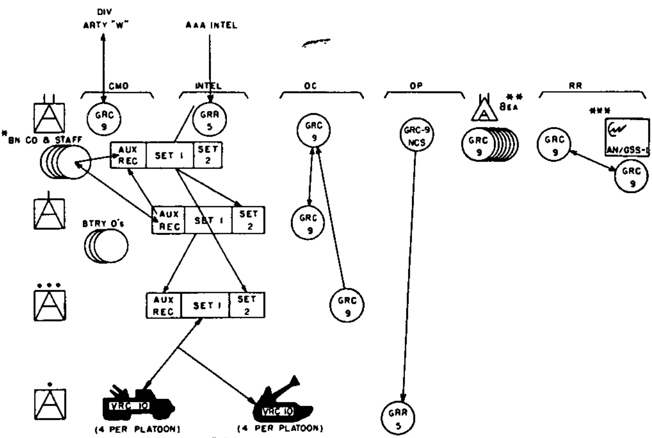

Figure 8. Self-propelled battalion (Infantry Division) antiaircraft mission radio nets.

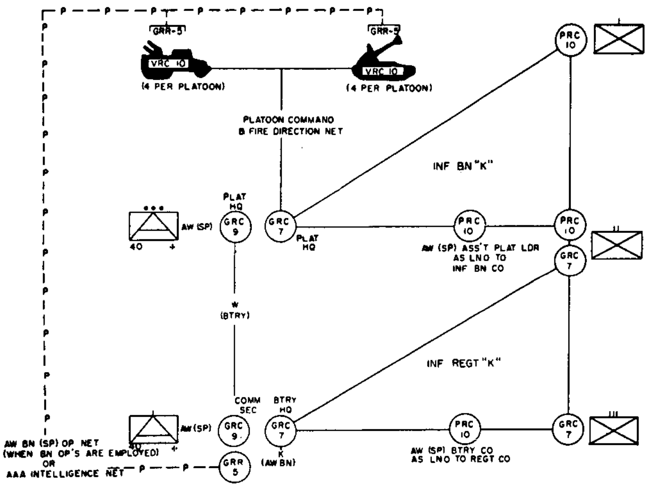

Figure 9. Self-propelled battalion (Infantry Division) surface mission radio nets.

of the same general type as that used within the division. When establishing an AA defense, the divisional unit will establish essentially the same facilities for communication as those required for AAOC operation at higher echelons (fig. 8). When assigned close support missions, divisional units will generally establish communication nets as indicated in figure 9.

d. Communication with Other Combat Arms. When AAA (AW) units are assigned missions which require close liaison with other combat arms, such as close support missions, radio communication becomes a vital problem. If available radio sets are of the same general type, with overlapping channels, assignment of operating frequencies in the overlap band will permit communications between the AAA (AW) unit and the supported unit. If radio sets of the units concerned are not of the same general type, it will be necessary to effect a temporary trade of radio sets between units so that each unit has the required number of radio sets.

46. Wire Nets

Figure 10 shows a type wire net for an AAA battalion (AW), nondivisional, in an AA role. Figure 11 shows a type wire net for a divisional type AAA battalion (AW) in a ground support role. Because of the limited amount of wire and wire equipment available, every effort must be made by all commanders to conserve wire. The need for wire communication to each installation must be carefully

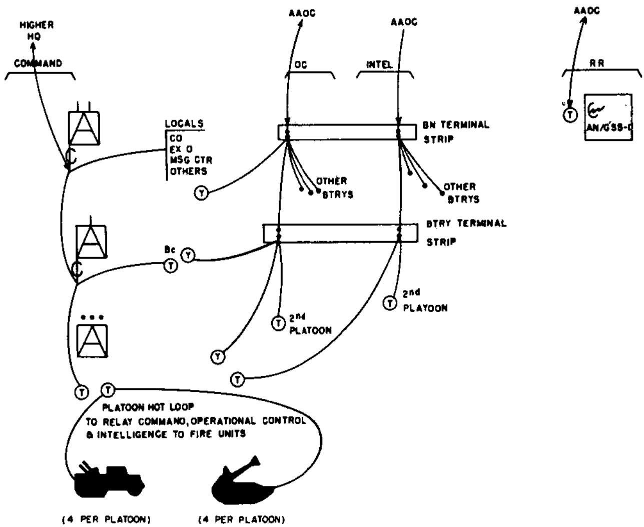

Figure 10. AAA Bn. (AW) wire nets, AA mission, under Senior AAOC.

considered. Command posts are located as near as possible to subordinate units in order to reduce the length of wire circuits. When no provision is made for wire communication personnel within the battery, personnel from the fire units must be trained to establish, operate, and maintain wire communication as well as radio communication.

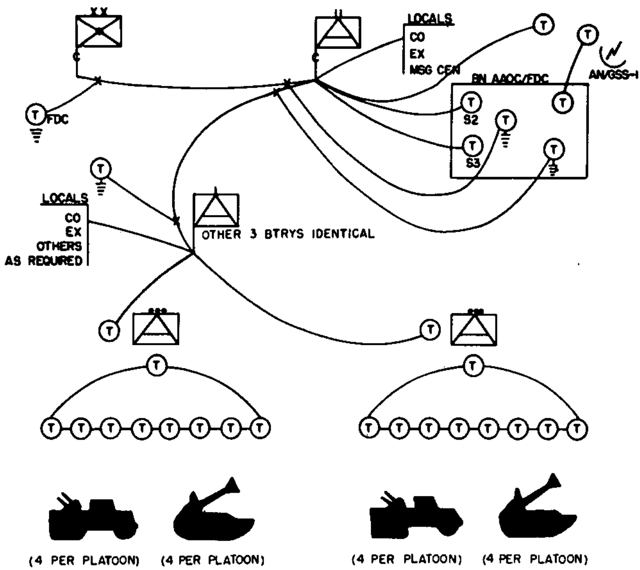

Figure 11. AAA Bn (AW) wire nets, surface mission (Div).

CHAPTER 6

OBSERVATION AND EARLY WARNING

47. Warning System

Adequate early warning information of the approach of aircraft is a prime requirement for the effective employment of AAA (AW). Adequate early warning will provide enough time for the personnel and equipment of the unit to be in the required condition of readiness to engage a hostile aircraft at the maximum effective range of the weapon.

a. Conditions of Air Defense Warning. The condition of air defense warning is announced to the senior AAOC by the air defense commander. The conditions of warning are:

(1) *Warning Red.* Hostile air attack imminent.
(2) *Warning Yellow.* Hostile air attack probable.
(3) *Warning White.* Attack by hostile aircraft improbable.

b. Conditions of Readiness. The condition of readiness will be directed by the AAOC, but any fire unit may assume a higher condition of readiness if conditions warrant. All units in forward areas normally maintain one of the following conditions of readiness:

(1) *Battle stations.* With a Warning Red, all

equipment is fully manned ready for immediate effective delivery of fire.

(2) *Standby.* With a Warning Yellow, weapons are partially manned, communication nets and command posts fully manned. Fire units are prepared to assume battle stations within a time limit prescribed by the AAOC.

(3) *Secure.* With a Warning White, command posts and communications are partially manned, surveillance and guard personnel are on duty, with all other personnel ready to assume battle stations within a time limit prescribed by the AAOC.

c. Action Status. Action status is the degree of engagement control imposed by the air defense commander through the AAOC on fire units in air defense. The terms are:

(1) *Guns Free.* Fire at any aircraft not identified as friendly.

(2) *Guns Tight.* Fire only at aircraft identified as hostile.

(3) *Hold Fire.* Do not open fire. Cease fire.

48. Functions of AAOC and AAAIS

Antiaircraft artillery information service properly employed, will furnish information on the activity of aircraft within a limited zone of surveillance. The AAAIS is not capable of providing warning early enough to eliminate the necessity for maintaining a constant condition of alert on the weapons. For detailed coverage of the AAOC and AAAIS in the zone of interior, communications zone, and combat zone, see FM 44–1 and FM 44–8.

49. Aircraft Identification

A comprehensive means of positive recognition and identification of aircraft is essential. Decisions as to conditions of readiness (secure, standby, and battle stations) must be based upon timely and accurate information as to the friendly or hostile nature of aircraft which have been detected. For detailed coverage of recognition and identification, see FM 30–30.

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CHAPTER 7

SECURITY AND PROTECTION

50. General

All AAA (AW) commanders must consider local defense capabilities while selecting fire unit positions and command posts. Automatic weapons positions are often widely separated and isolated, making it vitally important to establish effective local security for each position.

51. Passive Defense

A passive defense is designed without the expectation of taking the initiative or utilizing action weapons. It is based on concealment, dispersion, deception, and protection.

a. Cover and Concealment. The mission and time limitation with automatic weapons may restrict the amount of cover and concealment used. Time permitting, slit trenches, fortifications, shelters, and dugouts should be constructed (FM 5–15).

b. Dispersion. With automatic weapons dispersed in an antiaircraft defense, the problem of local security is increased. However, if the mission is primarily ground defense, the fire units should be concentrated in one locality to provide for more effective local security. Local security must be coordinated with adjacent or defended units.

c. Alternate and Dummy Positions. When a primary unit position becomes untenable or unsuitable for further occupation, the unit should be moved to an alternate position. Subject to the direction of higher headquarters, dummy positions may be prepared to deceive the enemy. Dummy positions are laid out a safe distance from all friendly troops and installations, and partially concealed to make them more realistic.

d. Blackout and Night Movement. Blackout discipline should be strictly enforced with all units in combat. An installation may be concealed during the day, but revealed at night because of the slightest light showing. Entrances to command post tents or shelters must have light locks and be checked frequently for light leaks. When a unit moves, it should be done at night with blackout lights.

e. Radio Silence. Radio silence is imposed to deny the enemy the opportunity of traffic analysis. Movements of units can be traced by listening to transmissions, even though the messages may be valueless. Communication during radio silence may be carried on by wire, messenger, or visual means.

f. Warning Signals. In combat, observation teams warn of enemy attack. Warning signals should be standardized so they may be understood by all friendly units. Different signals should be devised to indicate each type of attack.

g. Defilade. To hinder enemy observation, and provide protection of materiel and personnel, positions of AAA (AW) in a ground role should be placed so as to be shielded from direct fire of enemy artillery.

52. Local Security

a. General. Local security is provided by the effective use of personnel and materiel available to a unit. It includes all the measures necessary for protection against local attack. Local security plans and procedures must be closely coordinated with supported and adjacent units and conform with the area defense plan and area damage control plan.

b. Type of Attack. Antiaircraft units may expect any of the following types of attack:

(1) Infiltration.
(2) General breakthrough.
(3) Reconnaissance in force.
(4) Mechanized thrust.
(5) Parachutist.
(6) Glider.
(7) Guerilla.

c. Selection of Position. In selecting the AA position, the following factors are considered in attaining local security:

(1) Fields of fire for ground targets.
(2) Routes of approach to and from the position.
(3) Observation.
(4) Tactical advantage of ground.
(5) Camouflage.

d. Organization of Position. The defended area should be kept as small as possible, with the primary armament and available equipment within the perimeter defense. Machineguns and rifles are sited to form bands of interlocking fire around the perimeter to prevent enemy penetration.

e. Materiel. Weapons and equipment normally contained within an automatic weapons unit will be used for local security as follows:

(1) *Machineguns.* Machineguns are the primary ground defense weapons. They are

sited for interlocking, grazing fire through unobstructed fire lanes which are prepared on the far side of the wire or other obstacles. Multiple machine guns should be fired two barrels at a time only, and in short bursts, to prevent overheating. Alternate machinegun positions should be prepared.

(2) *40-mm guns.* The 40-mm gun, utilizing high explosive ammunition, is particularly valuable against enemy personnel in wooded or underbrush areas where air bursts can be obtained.

(3) *Hand grenades.* The added value of hand grenades is that they do not reveal the friendly position to the enemy.

(4) *Mines and booby traps.* Mines and booby traps, in addition to being effective in afflicting casualties on the enemy, also serve as warning devices. Mines must be laid in bands far enough outside the defended area to minimize the danger of injuring friendly personnel. Before mines are laid, clearance must be obtained from the engineer of the headquarters to which the automatic weapons unit is attached and also from adjacent units. See FM 20–32 for mine laying information.

(5) *Barbed wire.* Wire delays the enemy and provides a warning to the defended area. Wire should be strung from 50 to 100 yards from equipment. Noise-making devices may be attached to the wire. Details on wire obstacle construction are contained in FM 5–15.

(6) *Individual arms.* Wire and other obstacles should be covered by rifle, carbine, and machine gun fire from foxhole positions. Small arms positions should provide flanking and crossfire. Riflemen should be placed where they can provide protection for machineguns.

(7) *Rocket launchers.* Rocket launchers are located to cover probable avenues of approach in forward areas to provide for antimechanized defense. Launchers with supersensitive detonating ammunition are effective against enemy personnel.

(8) *Rifle grenades.* Rifle grenades provide a longer range effect against enemy personnel and lightly armored vehicles than do ordinary hand grenades.

f. Standing Operating Procedure. An SOP for local security is necessary for every unit. It must be coordinated with adjacent higher, and lower units, and be thoroughly understood by every individual. It will include:

(1) A plan for establishing and executing immediate local security upon occupation of position.

(2) A system of marking restricted areas, including mines and booby traps.

(3) The procedure for submitting mine and booby trap reports.

(4) Alert signals.

(5) The organization of a mobile reserve to support units needing aid.

(6) A system of challenges, passwords, and replies.

(7) An alert plan for manning primary equipment for ground defense.

(8) The establishment of ground observation and listening posts.

(9) Priorities for opening fire on ground targets.

(10) A plan for individual weapon ammunition supply and reserve.

(11) A plan for defense against CBR attack.

g. The Local Security Plan. The local security plan must be simple and flexible. It makes provision for establishing:

(1) An all-around perimeter defense.

(2) Sites for weapons.

(3) Sectors of fire for all weapons.

(4) Guards and listening posts.

(5) Guard details and orders.

(6) Booby trap and mine locations.

(7) Alert stations of personnel.

(8) Procedure in the event of perimeter penetration.

(9) Location of obstacles.

(10) Location of sleeping stations.

(11) Location and type of foxholes.

(12) Restricted areas.

(13) Night movement regulations.

(14) Firing lane preparation.

(15) Methods of communication.

(16) CBR defense.

(17) Chronological order of work to be done.

h. Conduct of Defense. In most cases AAA (AW) fire units are isolated and therefore must defend themselves. This presents a special problem because manpower is limited. At least one man must be on the alert at all times. When an infiltration

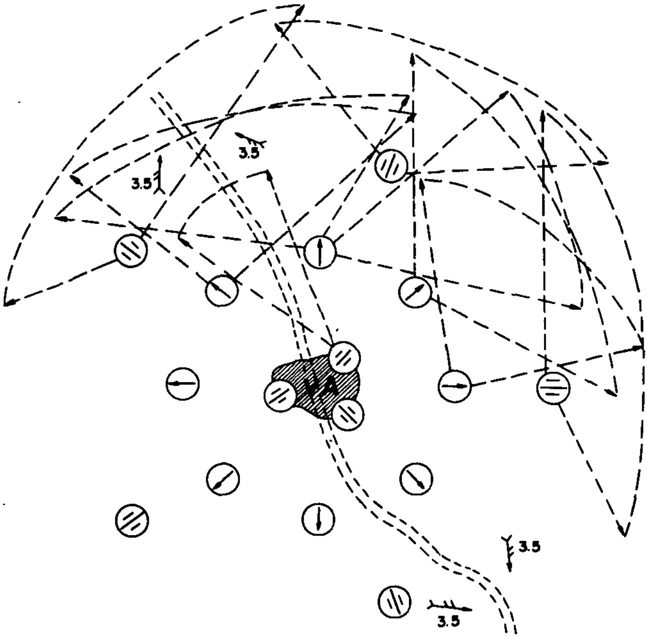


Figure 12. Perimeter defense in daytime.

becomes likely, men located on the perimeter remain alert and must conduct the defense with hand grenades until the enemy is definitely located or penetrates the perimeter. Ordinarily primary weapons do not fire until grenades and small arms fail to halt the penetration. If units are close enough together, supporting and flanking fire should be planned (fig. 12). At night when there is a threat of ground attack, weapons on the outer gun ring of the defense should be moved in and placed on the 500-yard ring. Positions should then be organized as strong points for local security (fig. 13).

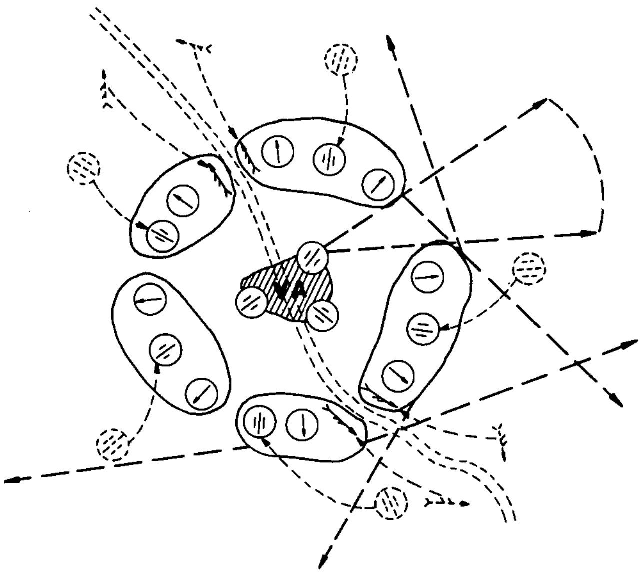


Figure 13. Perimeter defense at night.

CHAPTER 8

LOGISTICS

Section I. SUPPLY AND EVACUATION

53. General—Classes of Supply

a. General. General supply procedures and definitions are contained in FM 100–10 and FM 101–10.

b. Class I (Rations). Class I supplies consist of those articles which are consumed by personnel or animals at an approximately uniform rate, regardless of local changes in combat or terrain conditions. Rations are picked up daily by the battalion supply section. Issue is based on the daily battalion consolidated report of actual strength.

c. Class II (Supplies and Equipment Prescribed by TOE or TA). Battalion supply consolidates class II supply requisitions and forwards them through appropriate supply channels.

d. Class III (Petroleum Products). These supplies consist of fuels and lubricants used for all purposes except the operation of aircraft and flame throwers. Class III supplies are characterized by reasonably uniform demands, as in the case of class I supplies. They are, however, subject to sudden peak loads based on the tactical situation; they present a tonnage, transportation, and control problem. Solid fuels are the responsibility of the engineers. Quartermaster handles all other class III items.

e. Class IV (Miscellaneous Unclassified Articles). Class IV supplies are those for which allowances are not prescribed or are not otherwise classified. These supplies are issued by item; automatic supply is rare except in the case of certain medical items.

f. Class V (Ammunition). Class V supply includes both ordnance and chemical ammunition items. Flamethrower fuel and those demolitions and explosives which are closely allied with engineer activities are included in class V supply.

54. Supply Agencies

a. Antiaircraft artillery automatic weapons battalions have the necessary personnel and transportation to draw and deliver all classes of supply. Antiaircraft artillery groups do not function as a supply agency except for allocating critical supplies or ammunition.

b. Requisitions for supplies are submitted by batteries to the battalion supply officer, who consolidates and forwards them through appropriate supply channels.

c. When requisitioned supplies become available, the battalion is notified. Instructions concerning drawing and distributing supplies are normally published by higher headquarters. The battalion supply section issues and the batteries pick up the available supplies.

d. When AAA (AW) batteries are attached to other units, they will be supplied by the unit to which they are attached.

55. Airborne Supplies

a. The organic tactical loads of airborne units include an initial supply, or basic load, of ammunition. All other supplies carried by the airborne unit are limited and will last for a short time only. Personnel must be trained to conserve all supplies, particularly during the earlier stages of a mission when resupply is very difficult.

b. Supply of airborne units follows normal procedures, except that supplies for the airborne are transported by air until ground units have effected a junction with airborne troops.

56. Medical Agencies and Evacuation

a. For complete information on evacuation and medical agencies, see FM 100–10, FM 8–5, and FM 8–10.

b. The AAA (AW) battalion may or may not have attached medical personnel depending on the assignment, mission, and tactical situation. The medical detachment is an integral part of the battalion, attached for command, administration, and supply. Personnel of the detachment establish an aid station at battalion headquarters, with an aid man attached to each battery or platoon for first aid. Casualties are evacuated through the battalion or nearest aid station and from there as directed by higher headquarters.

Section II. TRANSPORTATION

57. Organic Transportation

The current TOE shows the transportation available to each type of unit. Mobile units normally have adequate transportation to move all equipment and personnel at the same time. Because of the limited number of cargo trucks in the self-propelled battalion, their allocation for use requires careful planning. The airborne battalion has the greatest problem because of limited organic transportation.

58. Mobility and Security

a. The mobility of an AAA (AW) unit depends largely on carefully prepared loading plans. In self-propelled and airborne units, each weapons mount must carry its own personnel and allied equipment. Platoon, battery, and battalion headquarters must have stringent loading plans because of the limited number of vehicles available.

b. During all motor movements, convoys should be protected against enemy air and guerilla attacks. By interspersing self-propelled weapons and manning other organizational weapons along the march column, a convoy will be assured of maximum protection against surprise attack.

c. Detailed information applicable to maintenance, operation, and security of motor transportation is found in FM 25–10.

Section III. MESSING

59. Responsibility

Due to the widely scattered positions of automatic weapons in a normal antiaircraft mission, the problem of messing becomes an acute one. The solution of the problem rests with the commanding officer.

60. Combat Messing

When a fire unit is located near another installation, arrangements should be made to have the antiaircraft troops mess with that installation. If no installation is nearby, food must be prepared by the battery or battalion mess and transported in insulated containers to the gun positions or prepared at the fire unit; there are so many disadvantages to the last arrangement, however, that every effort should be made to have personnel mess with an adjacent installation.

PART TWO

GUNNERY AND FIRE CONTROL DEVICES

CHAPTER 9

ANTIAIRCRAFT ARTILLERY (AUTOMATIC WEAPONS) GUNNERY PROBLEM

Section I. INTRODUCTION

61. General

a. A knowledge of the basic AAA (AW) gunnery problem is essential for a study of the sighting devices used with AAA (AW). Since these sighting devices are utilized on highly mobile weapons, and since these weapons are used in the defense of low-flying, hard hitting enemy aircraft, they are not expected to have round-for-round accuracy. Rather, the accuracy depends on the skill, speed, and knowledge of personnel operating them. It is therefore necessary, in training these personnel, to have a thorough understanding of the working parts of these devices, and the role those parts have in the overall solution of the gunnery problem.

b. Basically, the LAAA (AW) gunnery problem is to locate a point in space ahead of a target and to hit it. LAA (AW) sighting devices attempt to solve the problem with fixed assumptions. It is assumed, first, that the target is flying a straight course during engagement. Second, the target is assumed to be flying at a constant speed. These assumptions are logical due to the short engagement ranges of under 2,000 yards and the inability of modern high-speed targets to maneuver within a very short period of time. The third assumption is that the closest the target will come to the gun during its flight is a fixed distance or a fixed midpoint slant range. As explained in appendix III, variations in range effect the problem of correct lead very slightly short of 1,500 yards slant range.

62. Slant Plane Concept

To facilitate the understanding of the AAA (AW) problem and the sighting devices used in the solution, a geometric approach has been developed. This is known as the slant plane concept. The future position of the target is located by reducing the problem into one imaginary tilted surface, or slant plane, containing the firing weapon, the present position of the target, and future position of the target. In this mathematical solution, the weapon and target positions are reduced to points. (In the practical solution and analysis of the problem, the point representing the target reverts to its original shape, allowing for a small margin for error.) The slant plane concept is a simplified approach to the gunnery problem which places the single lead angle in an imaginary plane surface. With this accomplished, it remains only to apply superelevation. In antiaircraft automatic weapons this is a very small factor because of the high muzzle velocity and short effective range of the weapon.

Section II. ELEMENTS OF DATA

63. General

To present this gunnery problem, it is necessary to name and define certain geometric plane surfaces, points, lines, and angles used in the problem.

64. Planes

a. General. By definition, a geometric plane is an imaginary flat surface of infinite dimensions, and is established among other conditions, by a straight line and a point not on that line, or by three points not in a straight line.

b. Slant Plane. The slant plane is that geometric plane established by the target course line and the pintle center of the gun. The target course line for practical purposes is a straight line established by extending the longitudinal axis of the target fuselage to infinity. The pintle center of the gun is that point around which the gun bore moves laterally and vertically. As long as the target course line does not pass through the pintle center of the gun, a geometric plane surface exists and is called the slant plane (fig. 14).

c. Horizontal Plane. The horizontal plane is that plane established by the pintle center of the gun and all imaginary points at that same elevation, disregarding the curvature of the earth (fig. 14).

65. Points (fig. 15)

a. G. Point G is the gun and is defined as the pintle center of the gun.

b. T_o (T sub o). Point T_o is the present position (observed position) of the target and is defined as the location of center of mass of the target the moment a round is assumed to be fired.

c. T_p (T sub p). Point T_p is the future position (predicted position) and is defined as the point on the course line where the assumed round, if correctly aimed, will intersect the center of mass of the target.

d. T_m (T sub m). Point T_m is midpoint and is

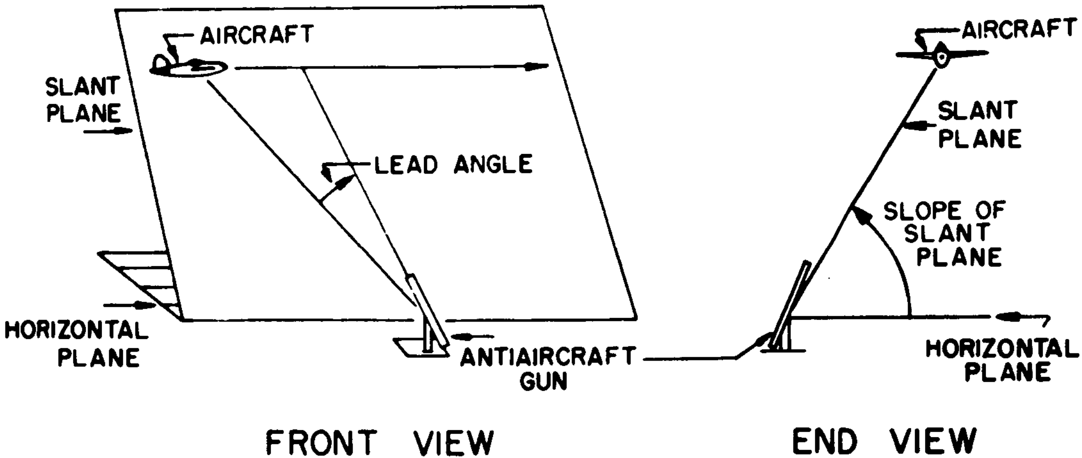


Figure 14. Slant and horizontal planes.

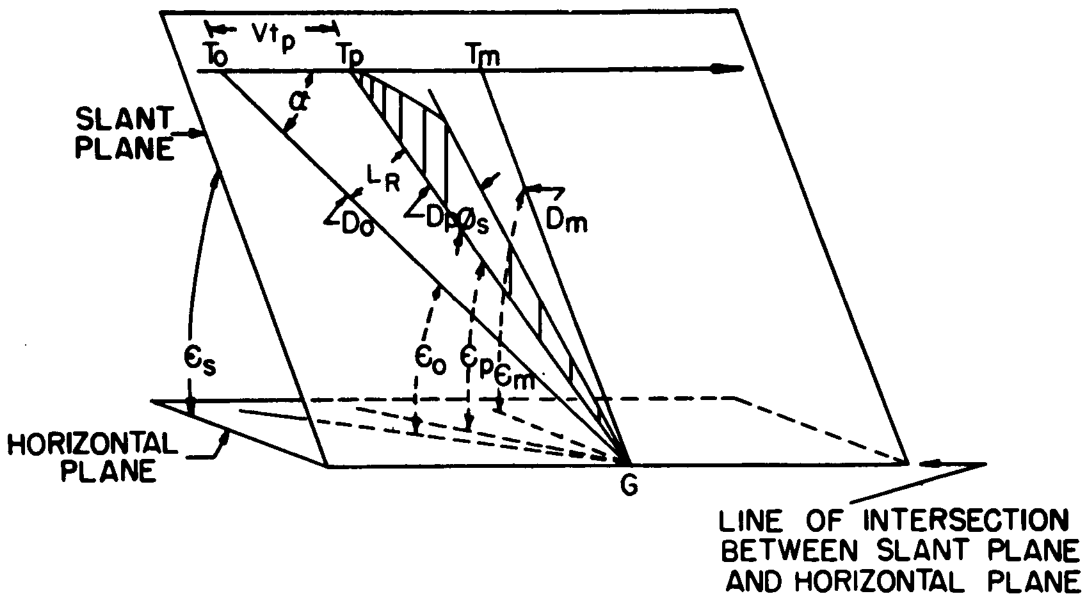


Figure 15. Points, lines, and vertical angles.

defined as that point on the course line at minimum slant range from the gun.

66. Lines (fig. 15)

a. D_o (D sub o). The line D_o is present slant range and is defined as the straight line distance in yards between the gun and the present position.

b. D_p (D sub p). The line D_p is future slant range and is defined as the straight line distance in yards between the gun and the future position.

c. D_m (D sub m). The line D_m is midpoint slant range and is defined as the straight line distance in yards between the gun and midpoint.

d. *Target Course Lines* (*fig. 16*). In any discussion of AA (AW) gunnery, the attitude of the target course line in space is of prime importance. To describe these different attitudes, target courses are named according to the altitude from the horizontal plane and the direction of flight in respect to the gun. Every target course will be described by two words; one describing altitude and the other describing direction.

(1) *Level.* A level course is formed by a target flying at a constant altitude.

(2) *Climbing.* A climbing course is formed by a target flying at increasing altitude.

(3) *Diving.* A diving course is formed by a target flying at decreasing altitude.

(4) *Incoming.* An incoming course is formed by the target flying toward a vertical line erected through the pintle center of the gun, perpendicular to the horizontal plane.

(5) *Outgoing.* An outgoing course is formed by a target flying directly away from a vertical

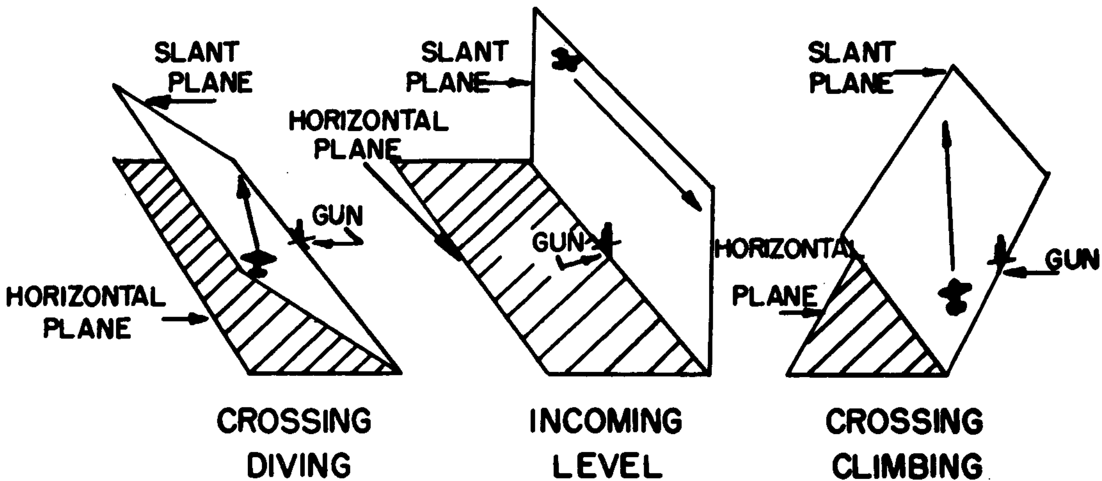


Figure 16. Target course lines.

line erected through the pintle center of the gun, perpendicular to the horizontal plane.

(6) *Crossing.* A crossing course is formed when the target course line does not pass directly over the gun.

(7) *Directly-at-the-gun.* A directly-at-the-gun course is formed when the target is flying directly toward the pintle center of the gun.

e. By combining the above names, any course can be described; for example, "Incoming Diving", "Crossing Level", "Climbing Outgoing" or "Diving Directly-at-the-gun."

f. Every target course line can be divided, for gunnery purposes, into two portions called legs. The *approaching leg* is that portion of the target course line along which the target is flying toward midpoint. The *receding leg* is that portion of the target course line along which the target is flying away from midpoint.

g. Vt_p (V small t sub p). The line Vt_p is target travel distance and is defined as the straight line distance in yards from the present position to the future position of the target. The letter V is the target speed (velocity) in yards per second along the course line. The letter t is the time of flight in seconds of the projectile assumed to be fired. The subscript p designates future position. Vt_p, then, has the value in yards of the speed of the target (in yards per second) multiplied by the time of flight of the projectile (in seconds) from the gun to the future position.

67. Angles (fig. 15)

a. E_o (E sub o). The angle E_o is present angular height and is defined as the vertical angle between the line of present slant range and the horizontal plane.

b. E_p (E sub p). The angle E_p is future angular height and is defined as the vertical angle between the line of future slant range and the horizontal plane.

c. E_m (E sub m). The angle E_m is midpoint angular height and is defined as the vertical angle between the line of midpoint slant range and the horizontal plane.

d. E_s (E sub s). The angle E_s is slant plane angular height and is defined as the vertical angle between the slant plane and horizontal plane measured perpendicular to their line of intersection.

e. *Angular Height Variations.*

(1) E_s, the slant plane angular height, cannot vary with any single target course line, because the position of one course line is fixed in space, just as the gun is at a fixed point.

(2) E_o and E_p, present angular height and future angular height, will both change in value as successive rounds are assumed to be fired along a target course line, provided that target course line does not lie in the horizontal plane. On level courses, E_o and E_p increase to midpoint and decrease thereafter. On climbing and diving courses they increase to a point other than midpoint where angular height to that point is equal to slant plane angular height and decrease thereafter. This point is located on the approaching leg of a diving course and on the receding leg of a climbing course.

f. ϕ_s (Phi sub s). The angle ϕ_s is superelevation and is defined as the vertical angle required to elevate the gun bore above the line of future slant range, in order to overcome the effect of curvature of trajectory caused by gravity. This angle varies inversely with the elevation of the gun bore and directly with range to the target (future slant range).

g. ϕ (Phi). The angle ϕ is quadrant elevation and is defined as the vertical angle between the axis of the gun bore and the horizontal plane.

h. α (Alpha). The angle α is the angle of approach and is defined as the angle formed by T_o, T_p, and G with the apex at T_o. This angle increases along a given course line as successive rounds are assumed to be fired and it varies, theoretically, from 0° to 180°. It always lies in the slant plane.

i. L_R (L sub R). The angle L_R is the required lead angle and is defined as the mathematically correct lead angle between the lines of present slant range and future slant range. This is a slant plane angle.

j. L_G (L sub G). The angle L_G is the generated lead angle and is defined as the angle between the tracker's line of sight and the axis of the gun bore (disregarding superelevation). The tracker's line of sight is a line projected from the tracker's eye through, or along, a sighting device. The axis of the gun bore (disregarding superelevation) is an imaginary line along which the axis of the gun bore would lie if the angle of superelevation were not set in. The generated lead angle and required lead angle are two distinctly separate angles. The required lead is a mathematically correct lead. The generated lead is the lead which actually exists on the gun. The problem, therefore, is to make the generated lead coincide with the required lead.

Section III. SOLUTION OF THE PROBLEM

68. General

With certain mathematically fixed points, lines, and angles established in and between the slant and horizontal planes, the AAA (AW) gunnery problem can now be solved. In conjunction with the mathematical solution to the problem, the practical and mechanical solution must also be explained. The problem of obtaining a hit is reduced to two basic requirements, line and lead. A set of four conditions or steps called links of the gunnery chain exist which, if collectively satisfied, will accomplish the two requirements.

69. Gunnery Chain

a. Link I. To establish and maintain the tracker's line of sight on center of mass of the target. The tracker's line of sight has been defined as a line from the tracker's eye through, or along, a sighting device. Link I, then, is to make the tracker's line of sight lie along the line of D_o, present slant range.

b. Link II. To establish the axis of the gun bore (disregarding superelevation) in the slant plane. With antiaircraft artillery automatic weapons, superelevation is mechanically applied. It is therefore necessary to stipulate, in academic definitions, that the angular height of the axis of the gun bore does not contain additional angle of superelevation.

c. Link III. To establish the correct amount of lead. This is to make the generated lead angle, L_G, equal to the required lead angle, L_R, or, having established links I and II, to make the axis of the gun bore (disregarding superelevation), lie along the line of future slant range, D_p.

d. Link IV. To establish the correct amount of superelevation. With the axis of the gun bore (disregarding superelevation) lying along D_p, the last step to obtain a hit is to elevate the gun bore a small amount necessary to overcome curvature of trajectory caused by gravity.

70. Requirements for a Hit

a. General. It can be seen that the men who aim and fire the gun would have little time to establish each link of the gunnery chain separately. Their immediate problem, while firing, is therefore reduced to two requirements for a hit. These are line and lead.

b. Line. This requirement is satisfied if the projectile is made to intersect the target course line within tolerance. In the *line tolerance,* a margin for error is introduced by the fact that the projectile need not intersect the narrow line of the projected longitudinal axis of the target fuselage in order to be effective. Intersecting the bottom or top of the fuselage is a hit. By definition, the line tolerance is one-half the angle subtended at the gun by the diameter of the fuselage of the target. The amount of this line tolerance increases with the diameter of the target fuselage and decreases with increasing range (D_p) to the target (fig. 17).

c. Lead. This requirement is satisfied, *after* line is obtained, when the projectile is made to intersect the target.

(1) *Lead tolerance.* Again, a margin for error is

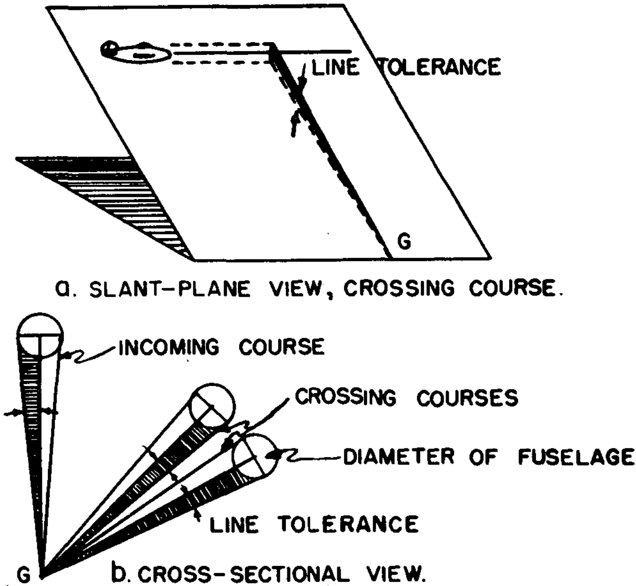


Figure 17. Line tolerance.

introduced. The projectile need not hit the center of mass of the target to be effective. An intersection with the nose or tail is classified as a hit. By definition, the lead tolerance is one-half the angle subtended at the gun by the length of the target fuselage. The amount of this lead tolerance increases with the length of the target fuselage, decreases with greater range (D_p) to the target, and increases with the sine of the angle of approach to minimum slant range and decreases thereafter (fig. 18 and app. III).

(2) *Mathematical solution of lead angles.* To fully understand the lead problem, it is

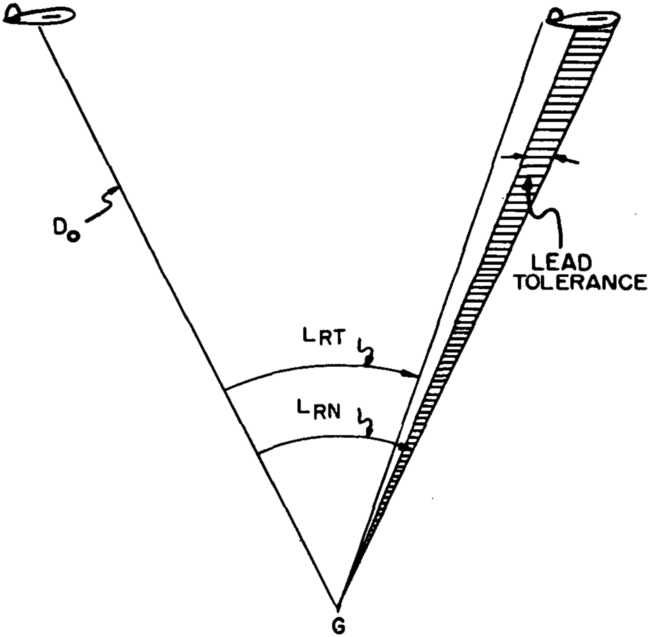


Figure 18. Lead tolerance.

necessary to have a working knowledge of trigonometry. In figure 15, the triangles in the slant plane are formed by the gun (G), the target's present position (T_o), future position (T_p), and midpoint (T_m). These points are mathematically located when a target is flying a certain course and a particular round is assumed to be fired. The mathematical problem is to determine the magnitude of the angle L_R, the lead angle required to hit the target. By applying the law of sines to the triangle

GT_oT_p, the following proportion is found: $\frac{\sin L_R}{Vt_p}=\frac{\sin \alpha}{D_p}$.

Solving the proportion for $\sin L_R$, the result is: $\sin L_R=\frac{Vt_p \times \sin \alpha}{D_p}$. Since antiaircraft automatic weapons have a high muzzle velocity, and are effective at short ranges, t_p may be considered a function of D_p, permitting the combination of values for t_p and D_p into the factor $\frac{t_p}{D_p}$, or the range factor. Thus, the required lead equation emerges in its final form: $\sin L_R=(V)\left(\frac{t_p}{D_p}\right)$ $(\sin\ \alpha)$. It can be seen by a complete mathematical analysis of this equation (app. III) that the amount of the required lead angle will increase with the speed of the target and the angle of approach to minimum range, but will change very slightly with range variations within effective ranges of antiaircraft automatic weapons.

Section IV. GENERAL APPLICATION AND ANALYSIS OF PROBLEM

71. General

With a knowledge of the mathematical solution to the gunnery problem, the officer supervising firing practice can analyze errors, and apply corrections in firing, by utilizing the links of the gunnery chain. In the critique of a particular firing course, each round must be sensed for line and lead. It is possible to do this through tracer observation, which is explained in chapter 10. The officer conducting the critique will then have line information; whether each round is *High*, *Low*, or *On* line within the tolerance, and lead information; whether each round is *Astern*, *Ahead*, or *On* in lead within tolerance. With this information recorded, the officer conducting the critique can analyze the problem with the tools at hand, the links of the gunnery chain, applying them first to line, then to lead.

72. Line

The supervising officer must realize that line shots must be obtained before corrections for lead (by the man on the gun) can be made. This is emphasized in Tracer Observation (ch. 10). He must also realize that obtaining line shots is as difficult, if not more so, than establishing correct lead, because of the smaller *line tolerance* provided by the shape of the target. The average AAA (AW) target fuselage is approximately 2 yards wide, or about 1 yard either way from the center. This 1 yard produces the line tolerance and, at a range of 1,000 yards from the gun, would subtend 1 mil, a very small margin for error. In addition, the line requirement must be satisfied, on crossing courses, by manipulating three links of the gunnery chain.

a. Link I. The tracker's line of sight must be kept on the target, and if possible the center of mass, at all times. The sighting device uses this line as the basic reference for its solution to the problem. Since automatic tracking devices are not available to AAA (AW), the physical and mental skills of the gun crew must be highly developed. Constant tracking practice is just as important to AAA (AW) accuracy as physical training is to the athlete. Techniques of tracking must be thoroughly covered in AA (AW) training, and even a highly trained tracker must continue practicing daily to maintain tracking skill.

b. Link II. Point the axis of the gun bore (disregarding superelevation) ahead of the target along the target course line. With the tracker's line of sight established, the axis of the gun bore (disregarding superelevation) is moved separately from the tracker's line of sight until it lies ahead of the target, pointing at the target course line, or lying in the slant plane. This operation is accomplished by manipulating the sighting device, or by the tracker carrying the target at a certain attitude in his sighting device. It again requires physical skill and technique. If link II is in error only a mil or two the round fired will be off line. The combined errors in link I and link II must be no greater than a average of 1 mil in one direction in order to obtain a line shot.

c. Link III. Since this link considers only the angular displacement between the tracker's line of sight and the axis of the gun bore (disregarding superelevation), an error in this link would merely place the round at some other point along the course line. Link III has no bearing on the line requirement.

d. Link IV. Superelevation in light AA (AW) is established automatically by mechanical linkages and cams when elevating or depressing the gun tube, or by setting it into the sighting device during orientation. This link, however, is critical to the line requirement on crossing courses. With links I and II established correctly, an error in superelevation of one or two mils will cause the projectile to pass above or below the target. Again, the combined errors in links I, II, and IV on crossing courses must be no greater than the average 1 mil in one direction in order to obtain a line shot. For incoming or outgoing courses, link IV will have no bearing on line because the angle of superelevation will be in the slant plane; $E_s=90°$.

e. Application.

(1) In summarizing the role of the links of the gunnery chain, links I, II, and IV establish the line requirement for crossing courses. If all of these links are satisfied within the line tolerance, line shots will result. However, it is possible for a link to be established incorrectly and be compensated for by errors in the opposite direction in the remaining links, resulting in line shots. The fact remains, however, that there can be no hits without line shots.

(2) On the firing range the supervising officer will set up a system for determining firing errors and correcting them after each weapon fires a course. For line performance, the tracers must be observed from a position in the immediate vicinity of the firing weapon. Sensings for line will be recorded by the observer, and a critique procedure formulated. A suggested procedure is as follows:

(*a*) Fire and observe the results.

(*b*) Question the gun crew. What did each crew member do during the firing?

(*c*) Analyze the facts obtained in the first two steps, and take positive corrective action.

(3) With a thorough knowledge of how the sighting device solves the problem, the gunnery troubles for any given firing course can generally be diagnosed by observation and questions. Each sighting device has a lever, knob, or handwheel, or the operator is provided with a rule or procedure of engagement, designed to permit proper adjustments for line performance. Men on the gun will seldom be able to diagnose the errors they have made. The observer (critiquing officer) behind the gun will experience difficulty in attributing the errors to any one individual, but he may be able to determine the cause of error by analyzing the links of the gunnery chain and thereby make accurate corrections in gunnery procedure.

73. Lead

Targets normally engaged by AAA (AW) average 16 yards in length or about 8 yards either way from center of mass. This 8 yards provides the average *lead tolerance* which, at a midpoint slant range of 1,000 yards from the gun is 8 mils, a greater margin for error than in the line requirement. However, the problem of satisfying the lead requirement depends on at least two links of the gunnery chain. For incoming and outgoing courses, three links are involved.

a. Link I. Just as in the solution of line, the tracker's line of sight is the basic reference line in the lead solution. Again, the tracker's line of sight must be kept as close to center of mass of the target as possible. Tracking the nose of the target, for instance, would allow no margin for error in front of the target. It follows, then, that training of trackers is just as important in the lead requirement as in establishing line.

b. Link II. Link II is of no importance to lead since it is strictly a step in placing the axis of the gun bore (disregarding superelevation) in the slant plane.

c. Link III. In order to establish the correct lead, it is necessary to make the lead angle generated on the gun equal to the mathematically correct required lead angle, within tolerance. Since AAA (AW) sighting devices are constructed with the assumption that the target is at a constant or fixed slant range, the error provided by this assumption causes rounds fired at extreme ranges to pass astern of the target (app. III). However, this error is absorbed by the lead tolerance within effective ranges of the weapon. The fact that the sight is producing correct lead within tolerance is called a *flythrough.* The AA (AW) sighting device is producing satisfactory lead results when one or two flythroughs on a firing course are obtained. Flythrough time interval is the total time during which flythroughs occur during any one firing course. It must be understood, however, that these sighting devices do not automatically produce correct leads or flythroughs. Their accuracy depends on the skill of the sight operator in *estimating* the correct lead. Again, human skill and training are essential.

d. Link IV. Since superelevation is a vertical angle, it is of significance to the lead requirement only if a target is flying an incoming or outgoing course, or if the slant plane angular height is 90°. Normally, errors in superelevation are easily absorbed in the lead tolerance. However, when added to other errors produced by links I and III, the superelevation error might cause the lead to be too great or too small.

e. Application.

(1) Summarizing the role of each link of the gunnery chain in establishing the lead requirement, links I and III are contributing factors for all courses, with link IV playing a small part during incoming and outgoing courses. If all these links are collectively satisfied within the lead tolerance, a hit will result, assuming correct line. However, errors in individual links may add to each other to produce too great or too small a lead, or may offset each other and produce hits.

(2) On the firing range, just as in line performance, the supervising officer will set up a system for determining errors in lead and correcting them on the spot. For lead information, the tracers must be observed from a downcourse position, at a prescribed distance from the firing gun (ch. 10). After each course, sensings for lead are communicated to the officer conducting the critique at the gun. The same procedure suggested for line can be used.

(3) Similar to line, each sighting device has a lever, knob, handwheel, or the operator

has a procedure of engagement designed to permit proper adjustment of lead performance. The operator of the sighting device, in observing tracers will, if line shots occur, be able to make lead adjustments, but will seldom be able to diagnose all the errors made. The officer conducting the critique will also experience difficulty in attributing the error to any one individual. However, he may be able to determine the cause by applying the links of the gunnery chain in analyzing the lead problem and improve the lead performance of the crew.

CHAPTER 10

TRACER OBSERVATION

74. General

Every round of ammunition fired by AAA (AW) cannot be expected to hit an aerial target. It is therefore necessary to make adjustments during firing. In order to do this, the operator of the sighting device must know the location of the projectile with respect to the target. Tracer ammunition will provide this essential information. However, the operator must be trained to sense tracers correctly in order to make the adjustments that are required to produce a hit. One of the most important duties is that of training gun crews to produce accurate fire. It is essential to understand tracer observation thoroughly in order to train gun crews properly.

75. Basic Principles

a. Superimpose Tracer and Target. In order for the observer to adjust fire, he must compare the range from the gun to the tracer with the range from the gun to the target. This will give him the direction of a lead error, if one exists. If the ranges are short enough, the observer can determine a difference between the two ranges by using normal stereoscopic vision. However, stereoscopic vision breaks down at a maximum range of about 500 yards.

Since targets are normally fired on at ranges greater than 500 yards, stereoscopic vision cannot be used. Instead, the observer must use the principle of superimposition. This means that the observer alines the tracer with, or superimposes it upon the target, in order to compare ranges to tracer and to target (fig. 19). Thus, lead can be judged. Because of the common tendency for gun crews and observers to attempt to judge lead without having the tracer and target alined, this first basic principle of tracer observation must be stressed. *Do not judge for lead until the tracer is alined with the target.*

b. Localize Vision. In figure 19, the tracer has been depicted as a single spot in the sky moving directly away from the observer's eye. However, in actual practice, the tracer will not appear as a fixed spot but rather as a curved path (fig. 20). This apparent curvature of the tracer path is called the illusion of curvature. It is an illusion because the curve does not actually occur. When a round is fired, it actually moves in a straight line away from the gun, except for the slight curvature of trajectory caused by the pull of gravity. Yet the tracer does appear to curve, and the point of maximum apparent curvature is called the *tracer hump.* This illusion of the tracer curvature is caused by the observer focusing his attention on a moving reference point, the target. At a certain instant, the eye of the observer is tricked into making him think the target has stopped in the sky, and the tracer is moving past the target instead of the target moving through the tracer path. This is a fascinating phenomenon to most observers, and there is a resulting tendency for

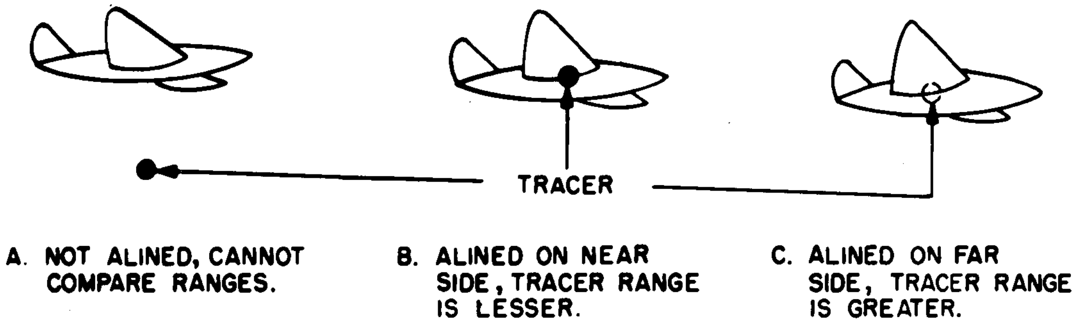


Figure 19. Superimposition.

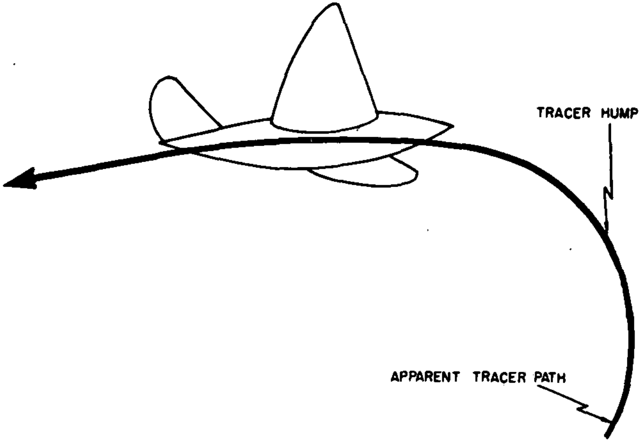


Figure 20. Illusion of curvature.

the observers to use this illusion for judging lead. However, tracers should never be observed near the tracer hump because it does not present factual lead information to the observer at the gun. Nor can the observer judge line performance by observing the tracer in the vicinity of the tracer hump. In order to obtain the desired information at the gun, the observer must focus his attention on the immediate vicinity of the target, as if looking through a telescope with a restricted field of view (fig. 21). Although the observer will see the curvature and the tracer hump in the actual field of vision, he must ignore them completely. From this analysis, the second basic principle of tracer observation is derived: *Localize vision to the immediate vicinity of the target.*

c. *Read Tracer Passing Target from Nose to Tail.* The target actually crosses the tracer path only once; it enters the path nose first and leaves the path tail last. Because of the illusion of curvature, the observer at the gun will see this passage when the tracer appears to pass by the target in a nose-to-tail direction. Under certain circumstances, the tracer will appear to pass by the target in a tail-to-nose direction (*a*, fig. 22). For example, on incoming courses the observer at the gun will sometimes see the tracer pass by the target twice; first in a tail-to-nose-direction, then in a nose-to-tail direction.

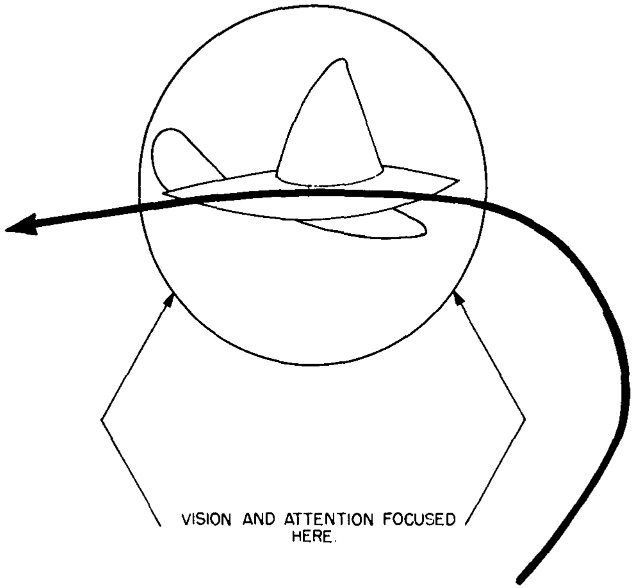


Figure 21. Localize vision.

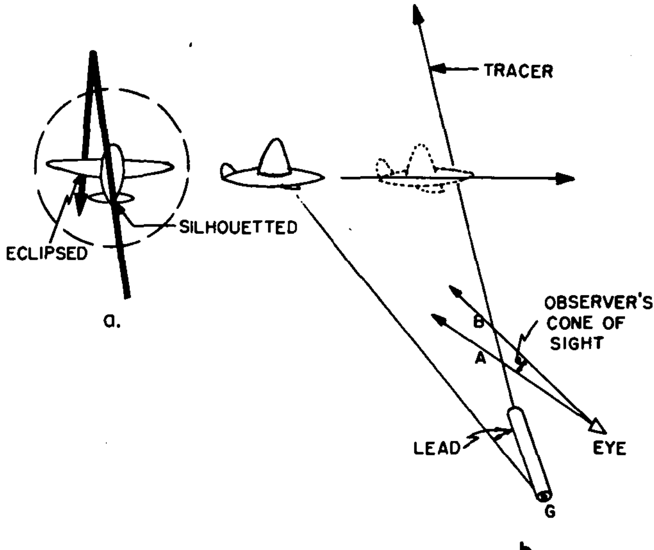


Figure 22. False picture.

Many observers make a tracer sensing in the first instance. This is wrong, because the tracer is not actually in the immediate vicinity of the target, but is somewhere short of the target (*b*, fig. 22). Therefore, the third basic principle of tracer observation is: *Read the tracer only when it is passing the target in a nose-to-tail direction.*

76. Observation at the Gun, Crossing Course

a. Line Information. The following are sensings for line information used by observers:

(1) *HIGH.* The tracer sensing called HIGH is illustrated in *a,* figure 23. By applying the test of superimposition to this picture,

it follows that lead information cannot be obtained. Hence, the projectile simply passes above the target as the target passes the tracer path.

(2) *LOW*. The sensing called LOW is illustrated in *c*, figure 23. As in the case with the HIGH tracer, this LOW tracer cannot provide lead information to the observer at the gun. The observer knows only that the tracer passes below the target as the target passes the tracer path.

(3) *ON*. The sensing called ON, as illustrated in *b* and *d*, figure 23, is made when a line shot occurs. A line shot occurs when the tracer pierces the cone of sight. The cone of sight is a rough cone with the apex at the observer's eye, having a cross section shaped as the contour of the outline of the target and extending to infinity.

b. Lead Information. The following are sensings for lead information used by observers:

(1) *AHEAD* (*b*, fig. 23). Line shots will provide lead information at the gun because of the principle of superimposition. When the tracer pierces the cone of sight at a greater range than that of the target, the tracer is eclipsed by the target during the passage of the target through the tracer path. The tracer reaches the target course line in front of the nose of the target and is therefore AHEAD.

(2) *ASTERN* (*d*, fig. 23). When the tracer pierces the cone of sight at a range less than that to the target, the tracer is sil-

houetted against the target during the passage of the target through the tracer path. The target crosses the point of intersection of the tracer path and target course line in advance of the projectile. When the nose of the target arrives at that point, the tracer will be silhouetted against the target until the tail or rear edge of the target clears that point. The tracer will then reach the point of intersection, passing to the rear of the target and is therefore ASTERN.

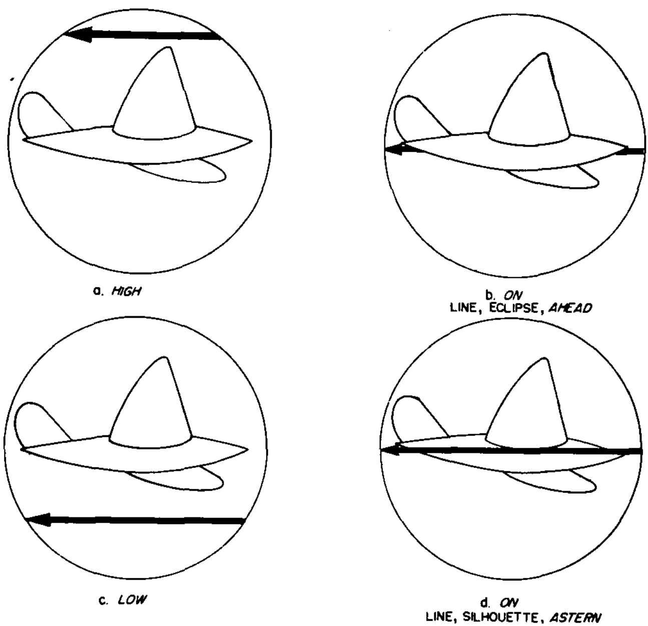


Figure 23. Line and lead sensings, crossing course.

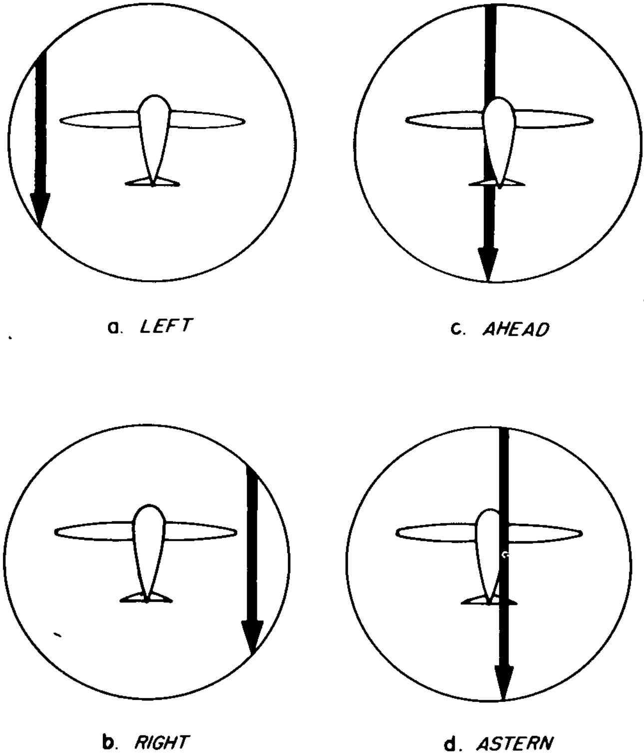


Figure 24. Line and lead, incoming course.

77. Observation at the Gun, Incoming Course

a. Line Information. The following are sensings for line information.

(1) *LEFT.* In *a*, figure 24, the observer knows that the tracer has passed to his left of the target and that no lead sensing can be made. It is therefore sensed as LEFT.

(2) *RIGHT.* In *b*, figure 24, the observer

knows that the tracer has passed to his right of the target and that again no lead sensing can be made. It is therefore sensed as RIGHT.

b. Lead Information. The following are sensings for lead information used by observers:

(1) *AHEAD.* In *c*, figure 24, the tracer has pierced the cone of sight at a greater range than that of the target because the tracer is eclipsed by the target. When the projectile crossed the target course line, it was in front of the nose of the target. It therefore had too much lead.

(2) *ASTERN.* In *d*, figure 24, the tracer is silhouetted against the target and therefore has too little lead.

78. Observation at the Gun, Outgoing Course

Figure 25 illustrates tracer sensings of LEFT, RIGHT, AHEAD, and ASTERN for an outgoing course. Notice that the tracer is always read in a nose-to-tail direction.

79. Observation at the Gun, Nonlevel Crossing Courses

Tracers fired at targets which are climbing or diving will produce the same picture to the observer as those for level courses (fig. 26). Merely tilt figure 23 to the desired angle of dive or climb of the target and the tracer still follows the target course line in a nose-to-tail direction. However, if the climb or dive becomes very steep, the sensings for line change from HIGH or LOW to LEFT or RIGHT (fig. 27).

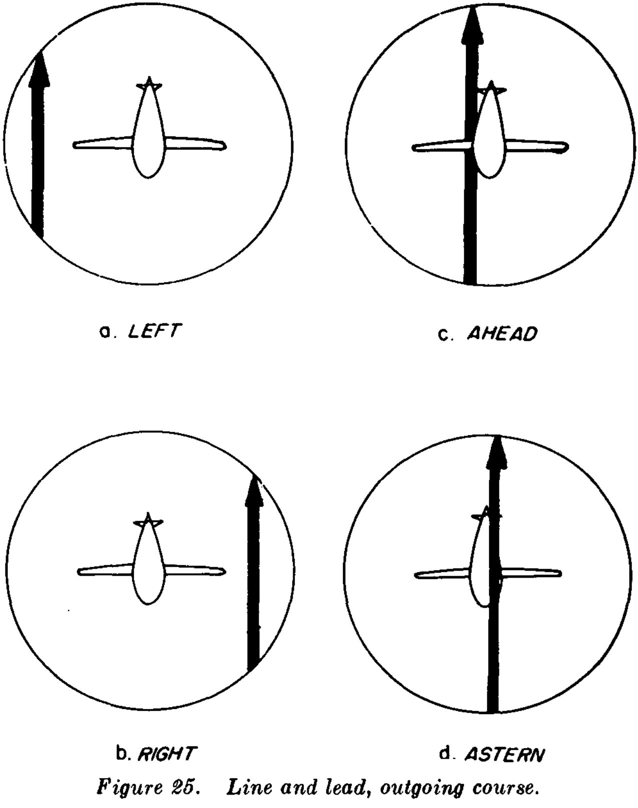


Figure 25. Line and lead, outgoing course.

80. Observation at the Gun, Directly-at-the-Gun Course

Tracer sensings for this type of course include line terminology only, since the required lead to hit the target is zero. There is no lateral or vertical movement of the target to the observer's eye. Therefore, the tracers are sensed as either HIGH, LOW, RIGHT, LEFT, or appropriate combinations of these four. Figure 28 shows three different tracer pictures

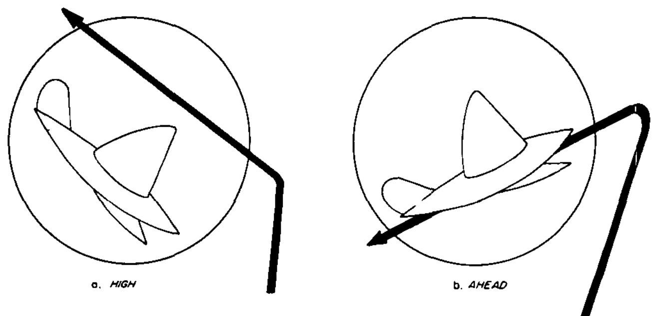


Figure 26. Line and lead, non-level course.

for a directly-at-the-gun course. Because the gun has had super-elevation applied to it, the tracer appears to climb from bottom to top of the picture, passing through the cone of sight, and then appears to drop from top to bottom of the picture. This drop or curve of the tracer is caused by the actual curvature of trajectory and is not an illusion. Whenever possible, the tracer should be read as it appears to drop from top to bottom of the picture, because this drop normally starts at a range slightly less than the range to the target. Reading the tracer from top to bottom, then, satisfies the basic principles of reading from nose to tail and in the immediate vicinity of the target.

81. Downcourse Observation

a. How to Observe.

(1) As long as an observer at the gun can see the target and the tracer, sensings for line can be made. In combat, tracer observations for both line and lead will be made only by observers at the gun. However, during the training phase, a gun crew can

profit from lead information obtained from nonline shots. Observers at the gun cannot provide lead information on nonline shots. There is a location known as the "down-

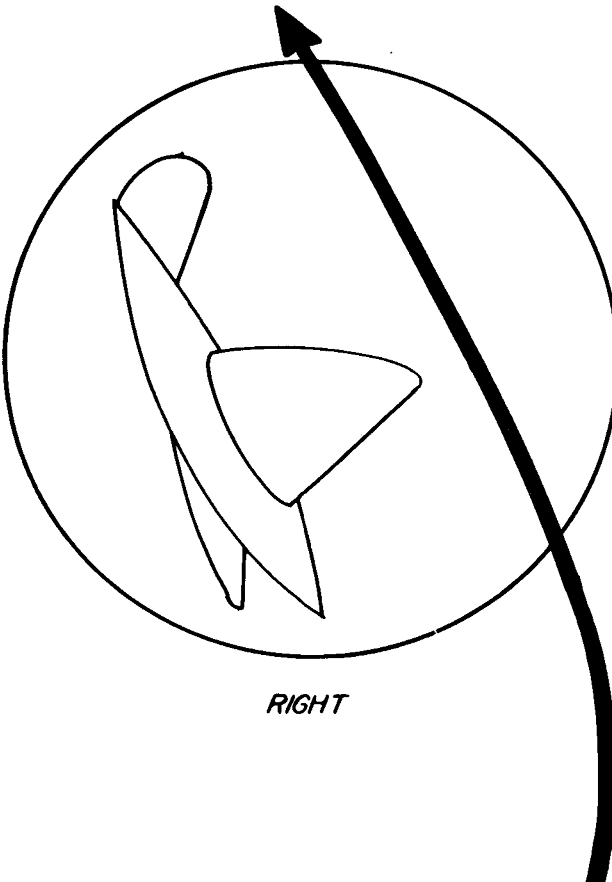


Figure 27. Line sensings, steep diving course.

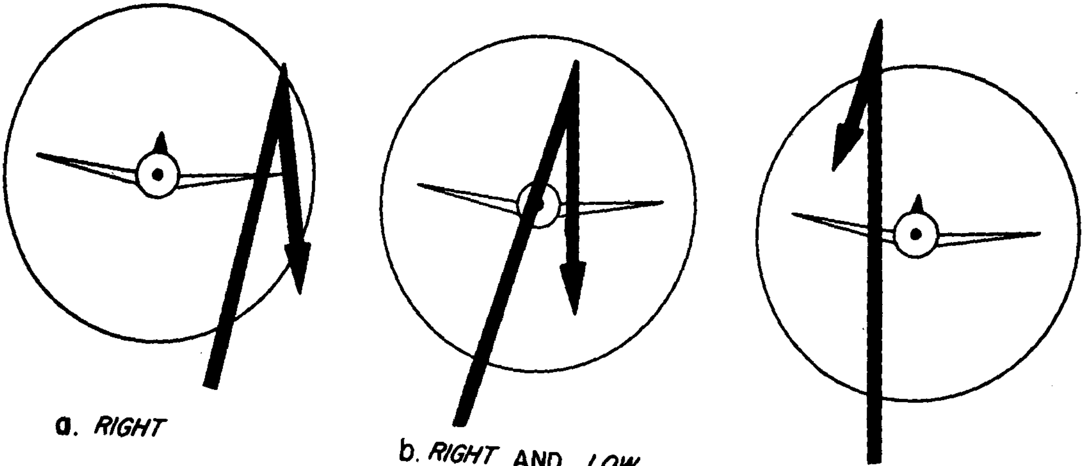


Figure 28. Line sensings, directly-at-the-gun.

course observation station" where an observer can obtain lead information. The downcourse observer is placed in the slant plane, a computed distance (*b* below) from the firing gun, in the direction of target flight. The observation station is located left of the gun for a right to left course, right of the gun for a left to right course, and to the rear of the gun for an incoming course. In *a*, figure 29 is shown the position of the downcourse observer, who is placed in the slant plane and the computed distance, *b* yards, to the right of the gun for the left to right course.

(2) From the downcourse station, the observer sees a unique view of the tracer hump. In *b*, figure 29, is shown the target on the approaching leg and the appearance of the tracer hump. The observer determines a lead sensing by noting the position of the hump in relation to the target. An imaginary line is projected from the hump, perpendicular to the imaginary target course line. If the intersection of this perpendicular line with the course line is anywhere on the target, the lead is correct and the sensing is ON (*d*, fig. 29). Likewise, if the perpendicular line intersects the course line in front of or behind the target, the sensings are AHEAD or ASTERN, respectively (*b* and *c*, fig. 29). It can be seen that, even though the projectile is off line, a lead sensing can still be made.

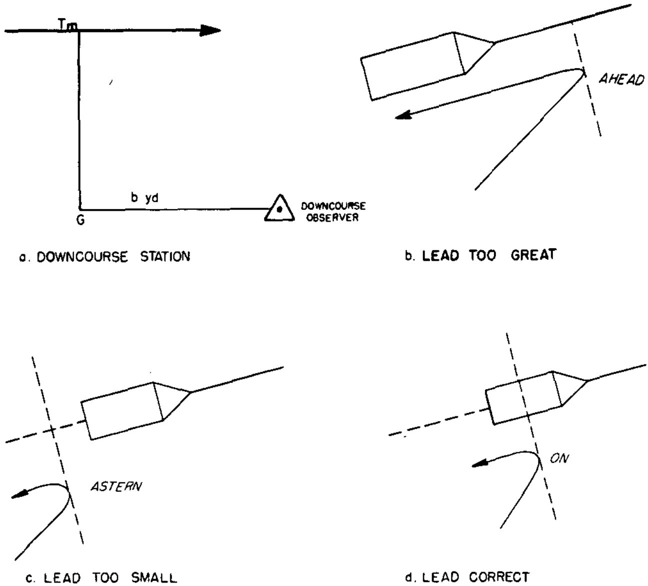


Figure 29. Downcourse observation.

b. Downcourse Distance. The distance of the downcourse observer to the firing gun is vital to the accuracy of the lead sensings. The equation used to solve for the downcourse distance, *b*, is:
Where

b=distance from gun to downcourse station
V=speed of the target in yards per second
D_m=slant range to midpoint
500=a constant factor

$$b=\frac{V\times D_m}{500}$$

To illustrate the above equation, the solution for the downcourse observer distance for a target traveling 200 miles per hour, at a midpoint range of 600 yards, is as follows:

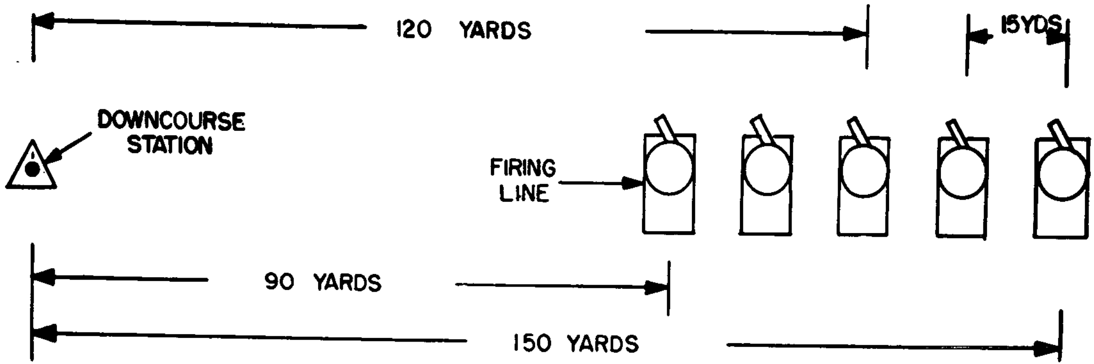
$$b = \frac{100 \times 600}{500} = 120 \text{ yards}$$

The downcourse observer would be stationed 120 yards from the firing gun.

c. Tolerance. The downcourse observer, in the case above, need not be stationed exactly 120 yards from the firing gun for sufficient accuracy of observation. There is a tolerance in this distance which may be convenient in observing for several guns on the firing line. This tolerance is $\pm\frac{1}{4}$ b, or in the case above, ± 30 yards. This means that the downcourse observer can be placed anywhere from 90 to 150 yards from the firing gun, and still be reasonably accurate. If a firing line contained 5 guns 15 yards apart, a single downcourse observer stationed 120 yards from the center gun could observe for all 5 guns with reasonable accuracy (fig. 30). It must be emphasized that the downcourse observer can obtain lead sensings for only one gun at a time.

82. Limiting Factors

a. Visibility Conditions. Tracer observation is an efficient method for determining relative ranges between the tracer, or projectile, and target when the background of the target is a deep blue sky that reveals the contrasting tracer. But when the sky becomes hazy so as to reflect sunlight into the observer's eyes, the observer cannot clearly distinguish the tracer in the equally bright sky. In combat, when the observer is watching the tracers of one gun,



$V = 100\,\text{yd}/\text{sec}$
$D_m = 600\,\text{yd}$

$$b = \frac{V\,D_m}{500} = \frac{100 \times 600}{500} = 120\,\text{yd}$$

Figure 30. Downcourse station.

several other guns may open fire on the same target, which would cause confusion. Visibility conditions affect tracer observation greatly. Variable density goggles may help to improve the visibility of tracers when the sky is hazy.

b. Target Speed. The observer will see the tracer in the immediate vicinity of a target that is 16 yards long and traveling at 400 miles per hour for only 8/100 second. If it is a line shot, the observer at the gun must see, in that very brief period of time, whether the tracer is silhouetted against, or eclipsed by, the target, in order to obtain a lead sensing. If an observer so much as blinks his eyes he may lose a valid sensing.

c. Range to Target. The brilliance of the tracer diminishes as the range from the gun to tracer and target increases. Tracer observation, for lead information at the gun, is limited to ranges of about 1,500 yards. Line information, however, is obtainable as long as tracer and target are visible.

d. Time Delay. Because of the time of flight of the projectile from the gun to the immediate vicinity of the target, the information obtained from a sensing is always delayed. In view of the fact that the target will be in the effective field of fire for only a few seconds, this delay is critical.

CHAPTER 11

SPEED RING SIGHTS

83. Basic Principles of Construction

a. Speed ring sights are the simplest but the least accurate of AAA (AW) fire control devices. They are designed on the principle of similar triangles. A small triangle within the mechanism is similar to the slant plane triangle in space, GT_oT_p (fig. 31). The basic speed ring sight has a rear peep element represented by the point G and a series of concentric circles as a front element, the center or hub of which represents the point T_p. The point T_o is represented at a point on one of the outer concentric circles where the center of mass of the target is carried while tracking. The concentric circles are called speed rings, and the points representing the slant plane points G, T_o, and T_p are given the symbols G', T_o', and T_p' (G prime, T sub o prime, and T sub p prime).

b. The radius of the individual speed rings depends upon the designer's conception of range (D_p) to the target, the distance the rings are placed from the rear peep sight, and the speed of the target which a particular speed ring must represent.

c. A speed ring sight is constructed by attaching a metal rod to the gun rigidly so that it is parallel to the axis of the gun bore. At the rear end of this rod, a small metal ring or peep sight is attached; at the front end attach a series of concentric metal rings, with the plane surface formed by those rings fixed

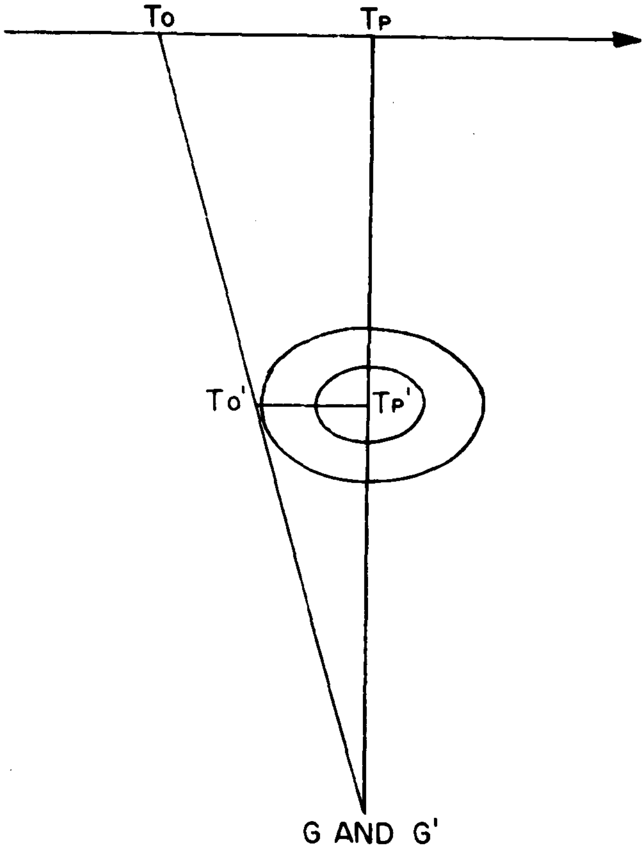


Figure 31. Principle of similar triangles.

perpendicular to the rod and to the axis of the gun bore. The size or radius of each speed ring must be mathematically fixed, with each ring representing a different speed of the target in miles per hour. Most speed rings are in increments of 100 miles per hour; one ring representing 100 miles per hour, another representing 200 miles per hour, etc. The radius of a speed ring may be determined as follows: With:

$\overline{T_o'T_p'}$ = radius of speed ring
V = speed of target in yards per second
t_p = time of flight of projectile
$\overline{G'T_p'}$ = distance, in yards, between peep sight and speed ring
D_p = slant range to the future position.

The rate between corresponding sides of similar triangles may be expressed:

$$\frac{\overline{T_oIT_p'}}{Vt_p}=\frac{\overline{G'T_p'}}{D_p} \text{ or } \overline{T_o'T_p'}=\frac{Vt_p\overline{G'T_p'}}{D_p}$$

To solve for the radius of a 100-mile-per-hour speed ring, the speed must be expressed in yards per second (50). D_p is fixed at 1,000 yards for all speed ring sights because it is an average range to targets for antiaircraft artillery automatic weapons. Assume that the distance between the peep sight and speed ring is 0.5 yard, an arbitrary distance that will make the sighting device small enough to handle. The factor t_p, which depends on D_p (1,000 yards), is then 1.23 seconds, assuming the sight to be mounted on a 40-mm gun. The equation then becomes:

$$\overline{T_o'T_p'} \text{ (Radius)}=\frac{50\times 1.23\times 0.5}{1{,}000}=0.03 \text{ yards or } 1.1$$
inches

84. Speed Ring Sight with Computing Sight M38

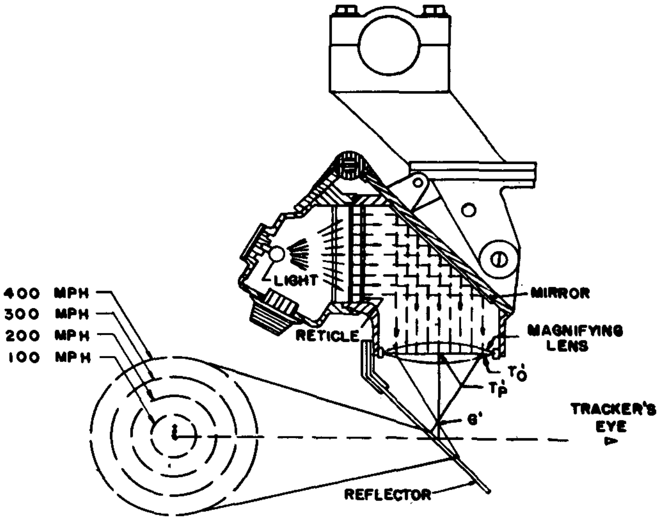
a. Front Sight. The speed ring sight used as an auxiliary to the computing sight M38 on the twin

Figure 32. Twin 40-mm speed ring sight.

40-mm gun has eight speed rings (figs. 32 and 59). The eight speed rings represent the required lead, at a midpoint range of 1,000 yards, for a target traveling 25, 100, 200, 300, 400, 500, 600 or 700 miles per hour, respectively. This sight has eight clock-hour wires which serve to hold the sight together and also aid the tracker.

① Photograph

Figure 33. Reflex sight M18.



② Schematic

Figure 33. Continued.

b. Rear Sight. The rear sight is a circular peep sight. For orientation, the rear sight can be adjusted vertically by loosening the two clamp nuts on the rear sight bracket and sliding the sight up or down. Lateral adjustment is made by loosening the clamp nut on the stem of the rear sight and sliding the peep sight left or right.

85. Reflex Sight M18

a. Description. The M18 reflex sight (fig. 33) on the multiple caliber .50 machinegun mount, consists of a mounting bracket, sight assembly, and a housing assembly. The sight assembly contains the optical system of the reflex sight, while the housing assembly provides artificial illumination when desired. The housing assembly can be raised by pulling out on the housing knob and rotating it 90°. In the up position, the housing assembly will allow daylight to enter the optical system of the sight assembly. The light rays, either from a natural or artificial source, pass through the sight assembly window. The diffused light, falling on a metal reticle, passes through the etched pattern, is deviated 90° by a mirror, and is focused at infinity by a double-lens objective in the objective assembly. The image of the reticle from the objective assembly strikes the reflector which is held at an angle of 45°. This reflector is a chemically treated glass plate which acts as both a mirror and a window. To the tracker the image appears out in space at the same range as the target. This image has 4 speed rings and 3 dots. The speed rings represent midpoint leads at 1,000 yards range for targets traveling 100, 200, 300, and 400 miles per hour. The lower dot is the hub or center of the speed ring reticle. The upper dot is used during orientation to establish superelevation and is approximately 10 mils from the dot at the hub. The dot located midway between the hub and the upper dot is used to vary superelevation in surface firing and represents approximately 5 mils of superelevation. For orientation, the sight is adjusted vertically by loosening the elevation clamp nut and turning the elevation adjusting screw, moving the image of the reticle up or down. For lateral adjustments, loosen the azimuth clamp nut and turn the azimuth adjusting screw, moving the image of the reticle left or right.

b. Operation. The tracker sights at the target through the reflector and at the same time, sees the image of the reticle mirrored from the reflector. He then moves the mount in azimuth and elevation until the image of the reticle is properly superimposed on the target. The image of the reticle passes down to the magnifying lens, which converges the light rays of the reticle image to a point G' between the lens and the reflector. The reticle image then diverges to the reflector, thence, to the tracker's eye. The reticle image can be said to create a cone with the base at the center of the lens, and the vertex at the point of convergence between the lens and the reflector. As the range to the target is increased, the diameter of the reticle image appears to increase proportionally although the actual size of the reticle remains constant. Thus it is seen that the speed ring always subtends the same lead angles, regardless of range to the target. The point T_o' is the point on the objective assembly corresponding to the tracking point. T_p' is the geometric center of the objective assembly. Point G' is the point of convergence of the reticle image. The position of the tracker's eye does not affect the gunnery problem. The only requirement is that the tracker look into the reflector in such a manner that the reticle image is reflected back to the eye, and at the same time, the target is visible through the reflector.

86. Gunnery Chain

a. Link I. The tracker's line of sight is established when the tracker alines the sights on the target (fig. 34). This requirement is not exacting

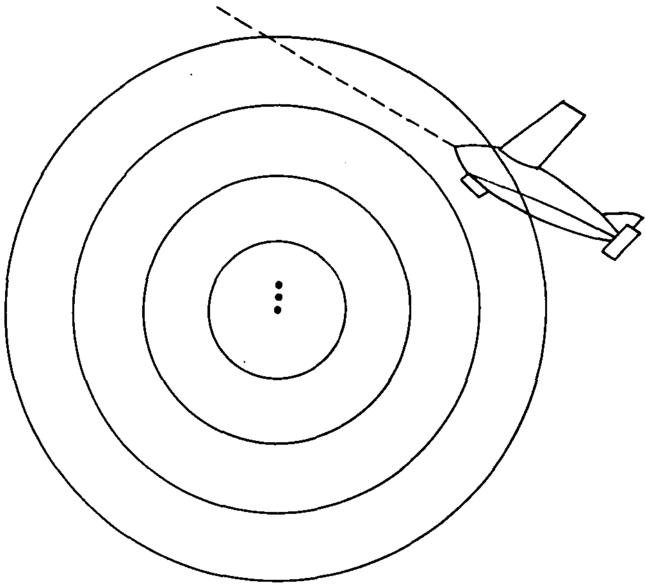


Figure 34. Link I.

since the other links of the gunnery chain will position the target at one specific spot in the sights.

b. Link II. The tracker keeps the nose of the target pointing toward the hub of the sight. This will establish the axis of the gun bore (disregarding superelevation) in the slant plane. The tracker visualizes the slant plane by extending the fuselage of the target to form the target course line, then positions the target in the sight in such a manner that the target course line passes through the center of the sight. In figure 34, the slant plane is above the hub of the sight. The axis of the gun bore is represented by the sight reference axis Therefore, the axis of the gun bore (disregarding superelevation) is not in the slant plane, and the sight must be elevated until the hub lies on the target course line (fig. 35). When a tracker is tracking properly along a target course, the target on a level crossing course will appear to be climbing toward the hub of the sight on the approaching leg, will appear to level out at midpoint, and will appear to be diving toward the hub on the receding leg. This appearance of the target rotating about the hub of a sight is called *image spin* and makes the establishment of link II a continuous operation. An aid to the establishment of link II is supplied to the tracker in the form of clock-hour wires radiating from the hub of some speed ring sights. These clock-hour wires assist the tracker in pointing the nose of the target toward the hub of the sight.

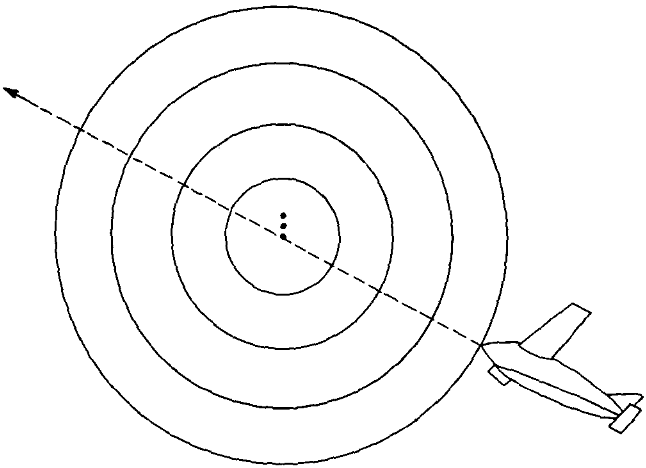


Figure 35. Link II.

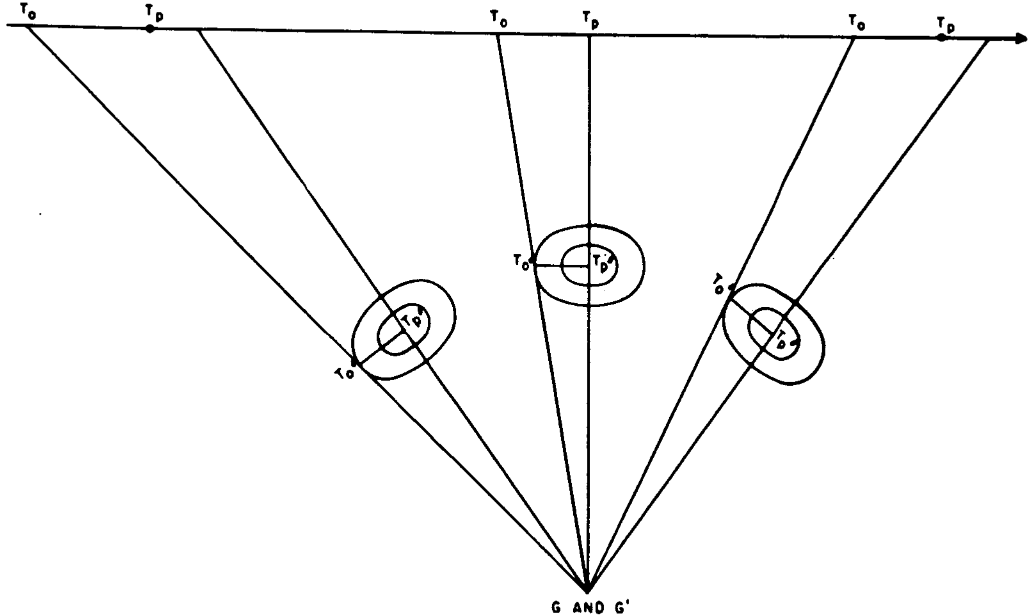


Figure 36. *Link III,* L_G *and* L_R.

c. Link III. The tracker makes the generated lead equal to the required lead or establishes the correct amount of lead (fig. 36). For any one target course, the required lead angle is constantly changing because the angle of approach and, to a lesser degree, the range to the target are constantly changing. When the tracker, utilizing a speed ring sight, carries the target on one speed ring the entire length of the course, the lead being generated is constant. Assuming the speed ring on which the target is tracked represents the correct speed of the target, the generated lead would equal the required lead only when T_p is in the vicinity of midpoint. To satisfy link III, the tracker must be able to estimate the speed of the target correctly. If the tracker should overestimate the speed of the target, the result would be the firing of an entire course with all rounds going ahead. To eliminate this possibility, the rule is for the tracker to adjust the sight picture so that the center of mass of the target will lie under a speed ring representing three-fourths of the estimated target speed (fig. 37). Using this rule, the tracker is given a leeway in target speed estimation, and will be assured of an effective flythrough. The factor of three-fourths speed is used merely because it is easily handled mathematically. A factor such as one-half, although easily handled mathematically, will produce flythroughs at a point beyond the maximum effective hitting range of the automatic weapons. The factor of three-fourths speed, then, gives the greatest assurance of at least one effective flythrough under combat conditions.

d. Link IV. Superelevation is set into speed ring sights during orientation and is a fixed value. In

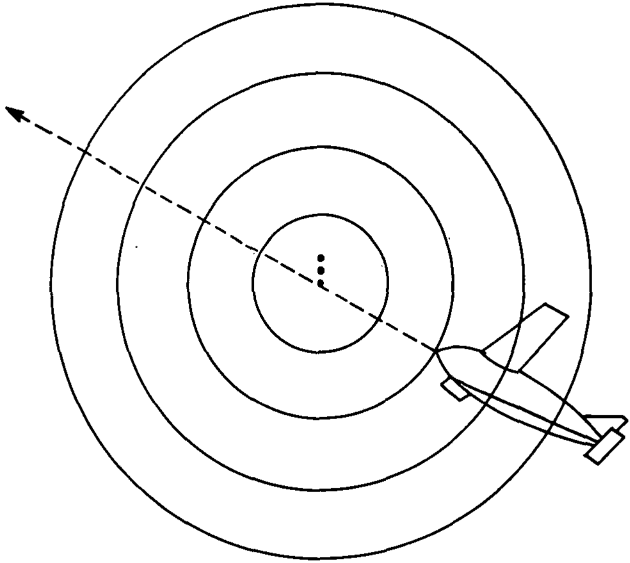


Figure 37. Link III, ¾ speed. Estimated target speed=400 mph.

every case the orienting point will be above the hub of the sight. The sight pictures, during orientation, will vary as depicted in figure 38, and should be properly established by use of orientation adjustments on each sight. The first step in the orientation of any speed ring sight is to boresight the gun tube on the orienting point.

(1) *Reflex sight M18* (*fig. 33②*). The upper dot should lie on the orienting point, thus establishing approximately 10 mils of superelevation. The dot midway between the hub of the sight and the upper dot is used only as a guide to permit the tracker in

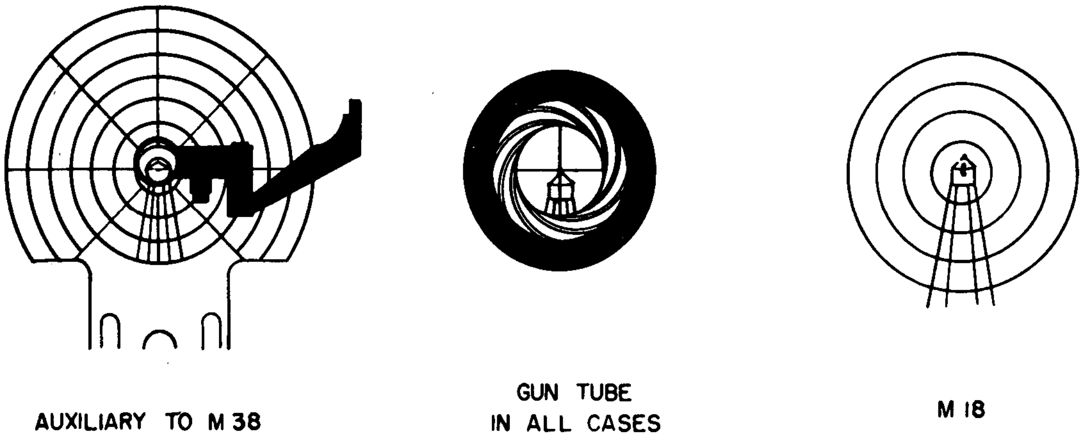


Figure 38. Superelevation, speed ring sights.

surface firing to set in any amount of superelevation from 0 to 10 mils by estimating from a 5 mil dot.

(2) *Speed ring auxiliary to computing sight M38 (figs. 32 and 59).* The peep sight is adjusted so that the tracker's line of sight, passing through the center of the peep sight to the orienting point, intersects an imaginary point two-thirds of the distance from the hub of the sight to the 25 mile per hour speed ring, in the 12 o'clock direction. This sight picture will establish approximately 10 mils superelevation.

87. Adjustments for a Hit

a. General. Speed ring gunnery does not necessarily depend upon tracer observation. If the tracker establishes the 4 links of the gunnery chain as prescribed, flythroughs will be obtained. If, however, the tracker is able to make a positive tracer sensing, a correction should be made under certain circumstances.

b. Line. If the tracers appear high, low, left, or right, depending upon the type of course, the tracker should adjust the fire. For line adjustment, merely move the hub of the sight. On crossing courses, move the hub to the right or left, depending on the correction needed. The basic rule is: *Move the hub of the sight in the direction you desire the rounds to go.*

c. Lead. Because of smoke, dust, or vibration of the gun, the tracker will rarely be able to obtain accurate lead sensings, and should therefore concentrate on tracking the center of mass of the target on the speed ring that represents three-quarters estimated speed, in order to obtain two flythroughs. If the tracker does make a lead sensing, an adjustment should be made only if the sensing indicates a hopeless case. A hopeless case is an astern far out on the approaching leg, an ahead in the immediate vicinity of midpoint, and an ahead anywhere on the receding leg of a course. These are hopeless cases because, if the firing were continued in that manner, no flythroughs could possibly occur. For a properly tracked course, tracers should appear ahead far out on the approaching leg, astern in the vicinity of midpoint, and ahead far out on the receding leg. Thus, even a properly tracked course has a hopeless case on the receding leg. To correct for a hopeless case, select a larger or smaller speed ring (at least a 100-mile-per-hour difference).

88. Speed Ring Sight Engagement Rules

a. Assuming the speed ring sight is properly oriented, the following rules for engagement will bring hits during all types of courses except one:

(1) Point the nose of the target toward the hub of the sight at all times.

(2) Track the center of mass of the target on the speed ring representing three-quarters estimated target speed.

(3) Keep firing.

b. The one exception to the rules is during a directly-at-the-gun course. In that course, the rule is to hold the hub of the sight on the nose of the target and keep firing.

CHAPTER 12
COMPUTING SIGHTS

89. Basic Principles of Construction

a. Computing sights are the primary means of fire control on the twin 40-mm gun motor carriage M42 and the 40-mm gun M1A1 on carriage M2A3. Computing sights are designed, as in the case of speed ring sights, to use the relationship between similar triangles (fig. 39). The sight produces a small triangle, $G'T_o'T_p'$, which the lead setter and gun pointer attempt to position similar to the slant plane triangle, GT_oT_p.

b. To produce a basic computing sight, as illustrated in figure 39, fasten a rod to the gun in such a manner that it will always be parallel to the axis of the gun bore (disregarding superelevation). At point G', fasten a second rod by a universal pivot, and along that rod attach a reflex sight in such a manner that it is parallel to the second rod at all times. Hence a gun pointer would have his tracker's line of sight displaced as the rod moves. Next, connect the two rods by a lead rack gear (represented in fig. 39 as $\overline{T_o'T_p'}$) with one end attached to the first rod at T_p' by means of a circular gear. This circular gear is arranged in such a manner as to allow the lead rack gear to be moved vertically about T_p'. The lead rack is attached to the rod holding the reflex sight at T_p' by means of the lead rack stud. Any movement of the rack will cause the tracker's line of sight to move an equal amount.

As the gear is turned, it causes the lead rack to be displaced a linear distance along the line $\overline{T_o'T_p'}$, changing the generated lead angle. Also, in order to have the sight triangle similar to and alined with the slant plane triangle, the lead rack must be able to rotate about the rod $G'T_p'$; hence, there is a need for the pivotal motion around the vertical axis through T_p'. In order to protect the lead rack and other mechanisms of the sight from the elements, these mechanisms are enclosed in a metal case called the computing box. With the computing box covering the lead rack and other mechanisms, the lead setter can no longer see the essential parts for adjustment of the sight triangle. Therefore, computing sights have external indicators to show the position of the lead rack and the amount of displacement of the lead rack stud from T_p'.

c. The first indicator is the target course arrow. The target course arrow is mounted outside the computing box on a bail shaped like a pail handle. The arrow is fixed to the bail in such a manner that it is always parallel to the lead rack. Therefore, when the lead setter adjusts the arrow parallel to the target course line, the lead rack will also be parallel to the same target course line. The second indicator is the speed knob, which is located outside the computing box. By setting a speed on the speed knobs, the lead setter causes the gear at T_p' to rotate. The rotation of this gear causes the lead rack to be displaced a linear distance, which in turn, causes T_o' to move away from T_p', establishing a generated lead angle. By observing the speed knob, the lead setter knows the magnitude of the generated lead. In order to make the sight triangle

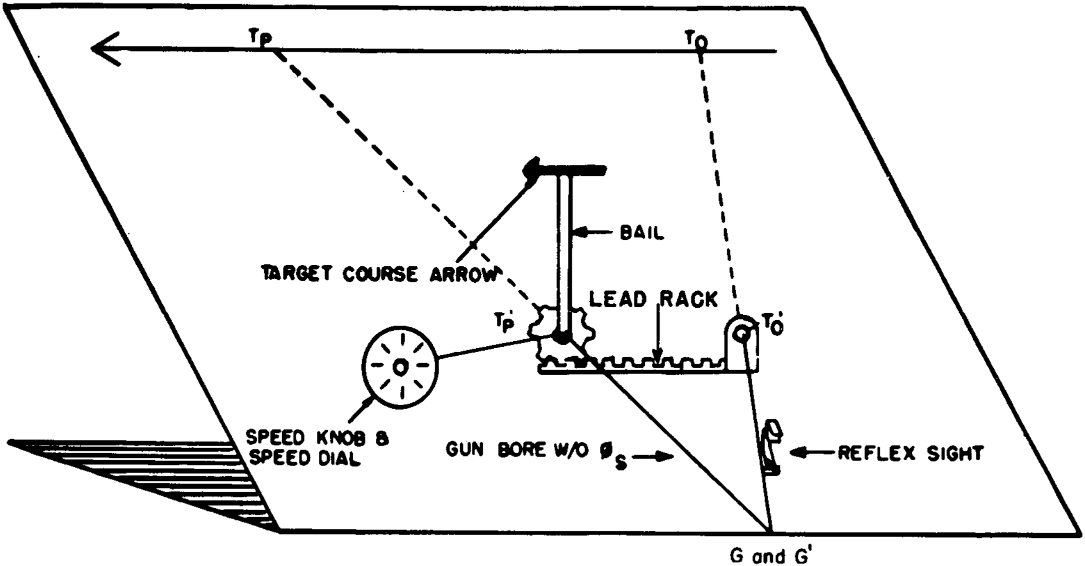


Figure 39. Computing sight principles of construction.

similar to the large slant plane triangle in space, two adjustments by the lead setter are necessary. First, the target course arrow must be positioned with the head of the arrow pointed in the direction of flight of the target, and parallel to the target course line, placing the lead rack in the slant plane. Second, full estimated speed of the target is set on the speed knob.

d. Computing sights are designed for a fixed range. This is illustrated by the following equation, which is solved for the length of the lead rack ($\overline{T_o'T_p'}$) for a target speed of 400 miles per hour:

$$\frac{\overline{T_o'T_p'}}{Vt_p}=\frac{\overline{G'T_p'}}{D_p} \text{ or } \frac{\overline{T_o'T_p'}}{200\ t_p}=\frac{\overline{G'T_p'}}{D_p}$$

To substitute a value for t_p, it is necessary to know D_p. For all computing sights used on 40-mm guns, this range is 900 yards. The sights, therefore, consider all targets to be at a range (D_p) of 900 yards, regardless of the true range. In the equation it can be seen that $\overline{G'T_p'}$ must also be established arbitrarily by the designer. For the M38 sight, this distance is 0.216 yard. The t_p of a 40-mm projectile for 900 yards is 1.09 seconds. The equation then becomes:

$$\frac{\overline{T_o'T_p'}}{200.1.09}=\frac{0.216}{900}$$

With only one unknown, the solution of the equation is: $\overline{T_o'T_p'}=\frac{218\cdot 0.216}{900}=0.0524$ yard or 1.88 inches.

The range factor in computing sights is held constant; yet this is not critical to the solution of the lead problem because of the method used by the lead setter to adjust for lead.

e. In the M38 or M19A1 computing sight triangle, there is only one rod instead of two as in the basic sight discussed above. This rod is called the swivel shaft. G' is still the pivot of this rod; however, T_o' is not the lead rack stud but is actually the stem ball located directly beneath the lead rack stud on the bottom of the vertical slide. Therefore, $\overline{T_o'T_p'}$ is a line parallel to the lead rack, passing through the center of the stem ball. T_p' is the point where this line intersects the vertical axis of the lead rack.

f. If there are two adjustments on the computing sight which affect the final position of the gun bore. The first is performed with the speed knobs. Turning the speed knobs in one direction causes the lead rack to move a linear distance, moving T_o' from T_p'. Turning the speed knobs in the other direction causes the lead rack to move in the opposite direction, moving T_o' toward T_p'. Assume a left to right crossing level course, with the gun pointer tracking the center of mass of the target; if the speed knob were turned to increase speed, the lead rack would move the sight off the target to the left in the direction of the tail, causing the gun pointer to track faster to get his sight on center of mass of the target; therefore moving the muzzle of the gun to the right ahead of the target, thus increasing lead. The second adjustment affecting the final position of the gun bore is with the arrow positioning mechanism. By turning the computing box positioning handwheel, the computing box is rotated about its vertical axis, thus repositioning the target course arrow and the lead rack. The lead rack stud moves with the lead rack and is a fixed distance from T_p' if the speed setting is not changed. Since the lead rack stud moves, the sight moves off the center of mass of the target. This forces the gun pointer to reposition the sight on the center of mass of the target, and in doing so, reposition the gun bore. Any movement of the bail will affect the final position of the gun bore in the same manner. If the arrow is positioned vertically by moving the bail, the lead rack will be repositioned also. The motion of the lead rack causes the sight to move, thus throwing it off target, and causes the gun pointer to reposition the gun bore while he moves the sight back on center of mass of the target.

g. When the lead setter initially positions the target course arrow parallel to the target course line, the arrow remains parallel to the target course line, even though the gun bore may move through 360° of traverse. As the gun traverses, the azimuth gear mechanism sends, by means of a flexible cable, equal but opposite rotation to the computing box positioning mechanism. This rotation positions the course arrow and lead rack, keeping them parallel to the target course line. This system of cable and gearing is called the course memory feature. The result of this feature is to automatically change the generated lead angle according to the constant change of the angle of approach along the target course line.

90. Solution of the Gunnery Chain

a. *Link I*. To establish the tracker's line of sight, the gun pointer places the intersection of the cross hairs on the center of mass of the target, and maintains that alinement. As with all on-carriage sights, the maintenance of that alinement is extremely important, but very difficult because of distractions such as the explosion and recoil of the gun, and smoke from the hot tube. With computing sights there is the added distraction of the sight moving off the center of mass of the target due to line and lead corrections made by the lead setter. The gun pointer, then, must be highly trained if the most effective use of the computing sight is to be obtained.

b. Link II. To place the axis of the gun bore (disregarding superelevation) in the slant plane, the rule is: *Adjust the target course arrow.* The axis of the gun bore (without superelevation) will always be in the slant plane when the line $\overline{T_o'T_p'}$ is in the slant plane. With the gun pointer establishing the tracker's line of sight on center of mass of the target, the line $\overline{T_o'T_p'}$ will be in the slant plane if the target course arrow is pointed in the direction of flight of the target, and is parallel to the target course line. The target course arrow is positioned by adjusting the computing box positioning handwheel and the bail. Once established for any one course line, link II will be maintained by the operation of the course memory feature, keeping the line $\overline{T_o'T_p'}$ in the slant plane. The one exception is for a target flying directly at the gun. In this case, set the speed knobs at zero, ignore the target course arrow, track the nose of the target, and fire.

c. Link III. To establish the correct lead, adjust the speed setting. The rule is: *Set the speed dial to read full estimated speed of the target.* The lead setter, when positive lead sensings are made, changes the speed setting by adjusting the speed knobs, which moves the reflex sight from the center of mass of the target. When the gun pointer reestablishes the reticle image of the sight on center of mass of the target, the gun bore is moved farther ahead or closer to the target, increasing or decreasing the value of the generated lead. The value of the generated lead angle will vary by the operation of the course memory feature according to changes in the angle of approach. The exception to the rule is for a target flying directly at the gun. In this case, set the speed knobs at zero, ignore the target course arrow, point at the nose of the target, and fire.

d. Link IV. The computing sight mechanically solves for, and produces, a variable amount of superelevation by a camming mechanism attached to the elevating mechanism of the gun bore. This superelevation varies, from maximum with the gun bore at +9 mils elevation, to zero when the gun bore is elevated to 90°. The origin of superelevation in the computing sight is the offset distance of the stem ball below the computer support trunnion axis (fig. 40). This offset distance subtends the angle formed by the line $\overline{G'T_p'}$ and a line parallel to the axis of the gun bore, passing through the vertical pivot box of the swivel shaft. At +9 mils elevation of the gun bore, this offset distance subtends 9 mils. As the gun bore elevates, the parallel link keeps the computing box level at all elevations of the gun bore, which causes a relative rotation of the stem ball. As the stem ball rotates about the computer support trunnion axis, the offset distance remains vertical and, as a result, the angle it subtends becomes smaller. With the gun bore elevated to 90°, the offset distance becomes parallel with the axis of the gun bore, hence the superelevation angle becomes zero mils.

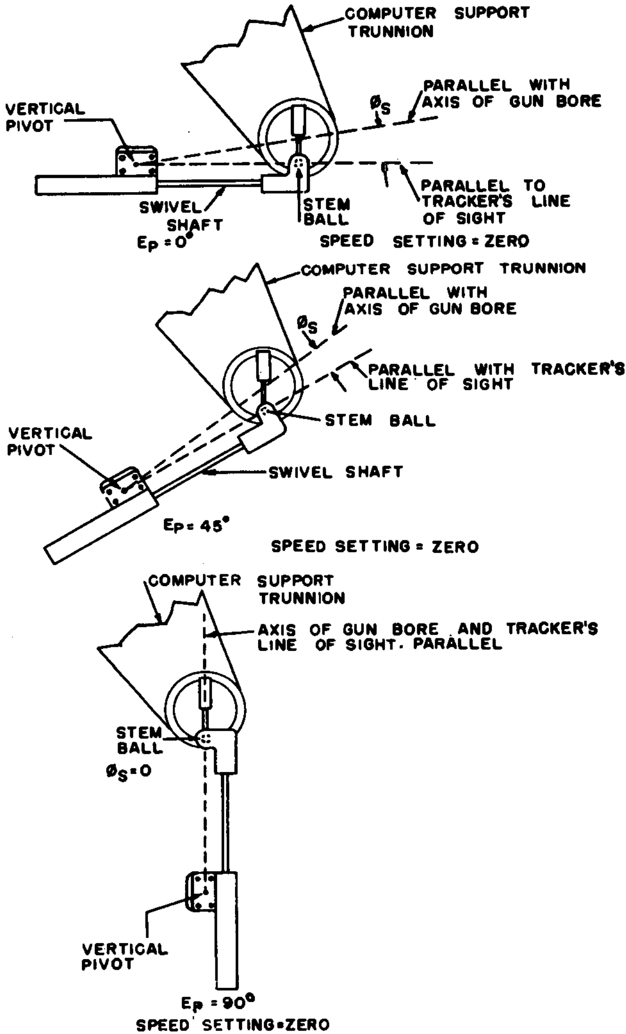


Figure 40. Superelevation mechanism, M38 computing sight.

91. Computing Sight M38.

a. Description (*fig. 43*). The M38 computing sight is the primary means of fire control on the twin 40-mm gun motor carriage M42. It consists of a computing box, two speed knobs with two speed scales graduated from 0 to 700 miles per hour on each knob, a target course arrow mounted on top of a bail, a computing box positioning handwheel, and a main support bar for housing a steel band used to transmit lateral motion to the gun pointer's reflex sight M24C. The reflex sight M24C is similar in operation to the M18 reflex sight, and has a light window, reticle and mirror, magnifying lens, and coated glass reflector (fig. 41).

b. Operaiton (*fig. 42*).

(1) *Target course arrow.*

(*a*) When the lead setter turns the computing box positioning handwheel, gear (1) rotates and supplies one input to the differential. The second input comes from the azimuth gear mechanism, along a flexible shaft, to worm gear (2). The two inputs are added algebraically, through a series of gears and shafts to gear (8), turning the azimuth base ring gear (9) which is the lower base of the computing box. When gear (9) turns, the entire computing box turns, thus positioning the target course arrow and lead rack horizontally.

(*b*) For hasty dive or climb adjustments, the lead setter grips the bail and positions the course arrow vertically. The rota-

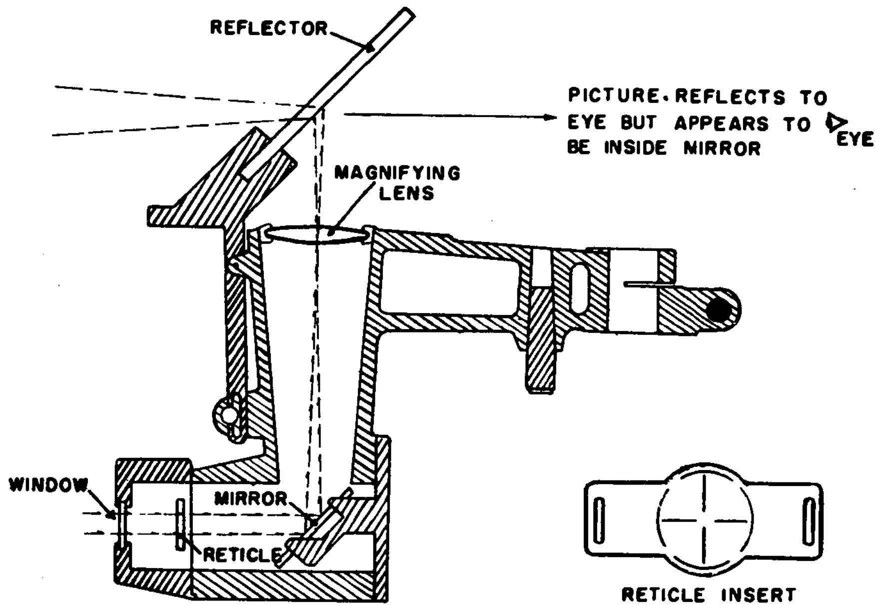


Figure 41. Reflex sight M24C.

tion of the bail turns the dive and climb scales (11), and the hub (10) which, by direct connection, turns gear (12) and lead rack guide (13), thus positioning lead rack (14) vertically parallel to the target course line.

(2) *Speed.* When the lead setter turns the speed knobs, shafts (A) are rotated. Yoke (B) directly connects shafts (A). This rotation turns gear (C) which moves lead rack (14) along guide (13), thus positioning the lead rack pivot (D). The movement of lead rack pivot (D) is converted to lateral and vertical components. The lateral component causes movement of guide (E) along slide (F), thus moving guide (H) which laterally positions the stem ball. The vertical component causes movement of the stem (G) along guide (H), thus vertically positioning the stem ball.

(3) *Differential action.* As the lead setter positions the lead rack for climb or dive angles, the lead rack (14) would move around gear (C), if gear (C) were stationary. The result would be a new speed setting on the speed knobs and the lead rack pivot (D) would change position. To prevent this from happening, a differential action takes place. The lead rack (14) revolves as a result of a vertical movement of the bail. Between one speed knob and the bail there is a friction pad (15) keyed to the knob and forced against the bail by springs; when the bail revolves, the speed

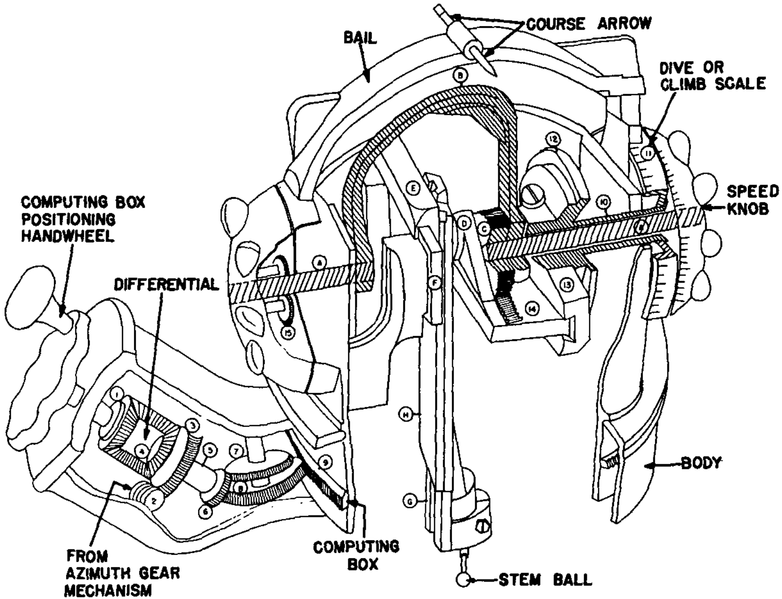


Figure 42. Computing box, M38 computing sight.

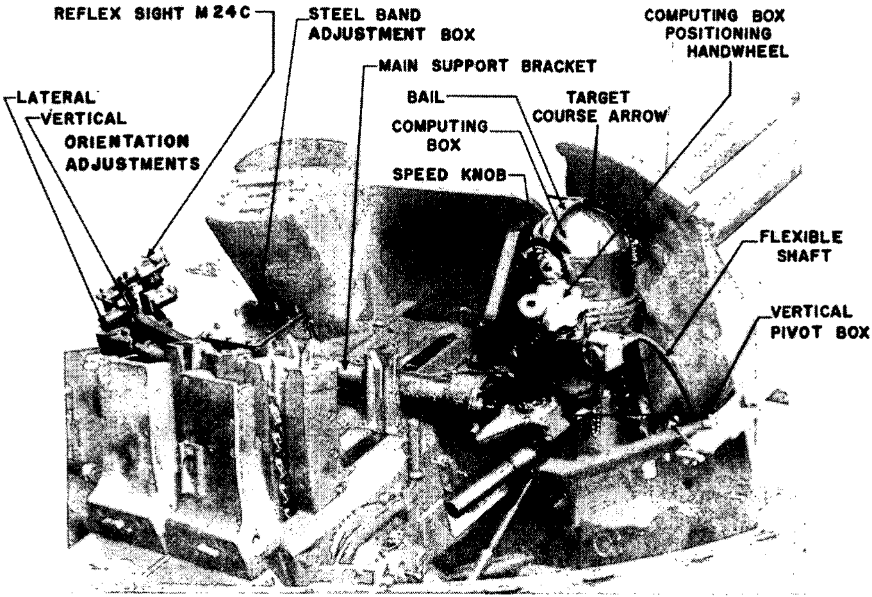


Figure 43. Computing sight M38.

knobs move with the bail because the friction of the pad is greater than the combined inertia of the speed knobs, gear (C), and lead rack (14). Thus, gear (C) and lead rack (14) remain meshed without change, leaving the readings on the speed knobs unchanged. When the lead setter turns the speed knobs to change the speed setting, the friction of the pad is not great enough to overcome the inertia of the arrow positioning mechanism; therefore, the pad rotates with the knob. The bail, however, remains stationary and no change in the position of the arrow occurs.

c. Transmission of Motion to Reflex Sight (fig. 43).

(1) *Lateral motion.* A steel band is used to transmit lateral motion to the reflex sight M24C. This band runs through the sight mechanism beginning and ending at the vertical pivot box. The steel band runs around two pulley wheels, one of which is connected to the reflex sight. The other pulley wheel, located in the vertical pivot box, receives motion from the swivel shaft and stem ball (fig. 43) when the lead rack is moved laterally. The band transmits this motion in equal amounts to the reflex sight. In order to prevent a lag in the transmission of motion, tension is placed on the steel band by means of an adjustable bearing roller mounted on springs. The band runs around the bearing roller. An adjustment moving the roller forward or backward will decrease or increase the tension on the steel

band. Tension on the steel band should be checked periodically. To make this check:

(*a*) Aline the sight on an object at a known distance.

(*b*) Make a vertical chalk mark on this object coinciding with the vertical reticle of the reflex sight.

(*c*) Grasp the reflex sight, pull it laterally in a counter clockwise direction at least 10°, then release the sight.

(*d*) With proper tension on the steel band, the vertical reticle will return to within 5 mils of its original position.

(*e*) If the tolerance is exceeded, adjust the tension on the steel band in the adjustment box on the left side of the main support bar, and repeat the check.

(2) *Vertical motion.* Vertical movement of the lead rack is transmitted to the stem ball, swivel shaft, and vertical pivot box. The vertical pivot box is mounted on the right side of the main support bracket and fastened to the main support box. Movement of the vertical pivot box rotates the main support bar inside the main support bracket, positioning the reflex sight vertically.

d. Computing Box Leveling. Before the computing sight can solve the gunnery problem accurately, the computing box must be level with the mount within the entire elevation limits of the gun tube. There is a tolerance in this requirement of ± 2 mils from 0° through 45° elevation, and ± 4 mils from 45° to 75°

elevation. To check and adjust the level of the computing box:

(1) Lock the turret in azimuth so that no movement of the gun will be possible during the leveling procedure.

(2) Place a gunner's quadrant on the quadrant seat of the gun trunnion. Center the quadrant bubble and record the reading.

(3) Place the gunner's quadrant on the computing box quadrant seat. Elevate the gun bore to 0°, 15°, 30°, 45°, 60°, and 75° in turn, and center the quadrant level bubble recording the quadrant reading at each test position. Approach each test position of the gun tube from the same direction to eliminate backlash errors.

(4) If any of the readings obtained in step (3) above exceed the reading obtained in step (2) above by as much as the specified tolerance, the computing box must be adjusted. To adjust the computing box:

(*a*) Bring the gun bore *up* to 0° elevation.

(*b*) With the quadrant on the computing box quadrant seat, and the reading obtained in step (2) above on the quadrant, center the bubble of the quadrant by adjusting the parallel link.

(*c*) Elevate the gun bore to 15°, 30°, 45°, 60°, and 75°, in turn, and record the reading of the gunner's quadrant at each test position after centering the quadrant bubble by manipulating the quadrant arm. Any deviations from level at all test positions should be within the specified tolerance.

If not, an error in procedure is evident. Repeat the procedure until the level is within tolerance at all test positions.

e. Initial Insertion of Superelevation. The stem ball must be offset to subtend 9 mils measured from the vertical pivot of the swivel shaft, with the gun bore at + 9 mils elevation. This adjustment should be made periodically to insure the correct stem ball offset distance; however, it need not be done each time the weapon is oriented. This distance is checked and adjusted by the following procedure:

(1) Lock the turret in azimuth.

(2) Place the gunner's quadrant on the quadrant seat of the left gun trunnion, center the quadrant bubble, and record the reading.

(3) Add 9 mils to the setting on the quadrant, place the quadrant on the machined quadrant seat on the breech casing, and elevate the gun until the quadrant bubble is centered.

(4) Again set the quadrant at the trunnion level reading obtained in step (2), above and place it on the vertical pivot box quadrant seat.

(5) Zero the speed setting on the speed knobs.

(6) Remove the protective bag at the base of the computing box, loosen the clamp screw on the stem ball, and turn the stem ball until the bubble is centered in the quadrant.

(7) Tighten the stem ball clamp screw, and replace the protective bag.

f. Orientation Procedure.

(1) Bore sight the gun on the orienting point (preferably 1,500 yards away).

(2) Set the target course arrow parallel to the

axis of the gun bore, with the head of the arrow pointed toward the breech (azimuth scale on the base of the computing box should read minus 1,600 mils).

(3) Place the target course arrow at an angle of dive of 50°. (On older sight models, with the BS mark at 17 mph, place the target course arrow at maximum dive.)

(4) Set the speed knobs to the reading marked BS.

(5) Adjust the reflex sight M24C in azimuth by turning the screw of the worm gear in the reflex sight support cap until the vertical reticle is on the orienting point.

(6) Adjust the reflex sight in elevation by loosening the clamp screw located on the sight support housing, then turning the screw of the worm gear located above the clamp screw on the sight housing. The worm gear moves along a gear rack to produce a vertical motion. When the horizontal reticle in the reflex sight is on the orienting point, tighten the clamp screws.

(7) Return the target course arrow and speed knob to standby settings.

g. Design. The M38 computing sight requires special adjustments in order to compensate for superelevation while orienting. Steps (2) and (3) in *f* above will aline the lead rack in such a position that when step (4) is completed, the lead rack has moved vertically, moving the reflex sight up the approximate amount of superelevation. This procedure effectively compensates for superelevation and produces the same result as though the stem ball had been adjusted in order to eliminate and reinsert superelevation for each orientation.

92. Computing Sight M19A1

The M19A1 computing sight (fig. 44) is the primary means of fire control on the 40-mm gun M1A1 on carriage M2A3. It solves the gunnery problem exactly the same as does the M38 computing sight and is constructed, mounted, and operated the same, with the following exceptions:

a. The main support bar is extended to hold an additional reflex sight M24C on the right end.

b. The computing box, computing box positioning handwheel, and vertical pivot box are mounted to the rear of the main support bar, with a longer parallel link and an added vertical deflection linkage.

c. As with the M38 computing sight, a steel band is used as the means of transmitting lateral motion to the reflex sights. This band runs through the entire sight supporting mechanism, beginning and ending at the vertical pivot box. A pulley wheel is attached to each rflex sight at each end of the main support bar. The steel band runs around, and is pinned to. these two pulley wheels, then continues around a third pulley wheel in the vertical pivot box. This third pulley wheel is rotated by the swivel shaft, and lateral movement of the stem ball, when the lead rack is moved laterally. The tension of the steel band is regulated like the band in the M38 computing sight.

d. A series of linkages, between the vertical pivot box and the main support bar, provide the means of positioning the reflex sights vertically. An arm is attached rigidly to the vertical pivot box; fastened

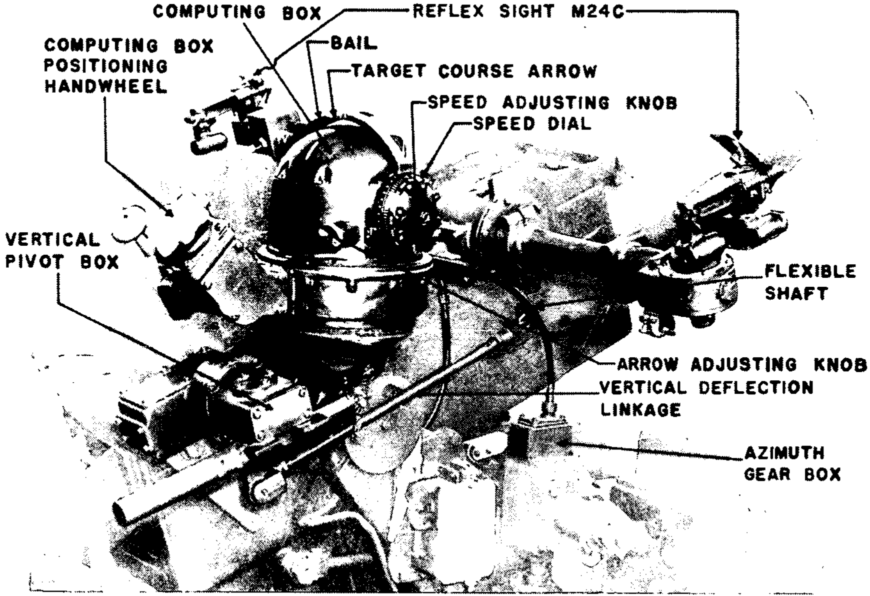


Figure 44. Camputing sight M19A1.

to this arm is the vertical deflection linkage. Another arm is attached to the other end of this linkage, which in turn is attached rigidly to the main support bar. As the vertical pivot box rotates vertically, the motion is sent through the vertical deflection linkage to the main support bar, which rotates on its longitudinal axis and elevates or depresses the two reflex sights simultaneously. The angle turned by the reflex sights must be the same angle rotated by the vertical pivot box, since the motion of the vertical pivot box is obtained from the vertical movement of the lead rack, through the connecting stem ball and swivel shaft. A check and adjustment should therefore be made when the sight is installed and at regular intervals thereafter. To make this check and adjustment, the procedure is:

(1) Set the computing box an at azimuth of $\pm$ 1,600 mils.
(2) Set the target course arrow at the maximum angle of dive.
(3) Set the speed at zero
(4) Place a gunner's quadrant on the vertical pivot box quadrant seat. Adjust the quadrant arm to center the level bubble and record the reading.
(5) Place the quadrant on the reflex sight in a stationary position. Adjust the quadrant arm to center the level bubble and record the reading.
(6) Change speed from 0 to 700 miles per hour.
(7) With the quadrant still on the reflex sight, adjust the quadrant arm again to center the level bubble, and record the reading.
(8) Again place the quadrant on the vertical

pivot box quadrant seat, adjust the quadrant arm to center the level bubble, and record the reading.

(9) The difference between the two readings taken on the vertical pivot box and those taken on the reflex sight will give two angles which should be within 1 mil of each other.

(10) If the two angles turned are not the same within 1 mil, loosen the two lock nuts on the vertical deflection linkage and adjust the sights by rotating the turnbuckle. This necessitates a trial and error method of adjustment. Adjust the turnbuckle, and check the angles turned by the vertical pivot box and the reflex sights until those angles are within tolerance.

e. Computing Box Leveling. The M19A1 computing box must be level throughout the entire elevation limits of the gun tube and within a tolerance of ± 2 mils. The leveling procedure is:

(1) Fine level the gun mount.

(2) Place a gunner's quadrant on the sight bracket quadrant seat.

(3) Elevate the gun bore to 0°, 15°, 30°, 45°, 60°, and 75°, in turn, and record the gunner's quadrant reading at each test position. Approach each test position from the same direction to eliminate backlash errors.

(4) If the readings obtained in step (3) above exceed ± 2 mils, the computing box must be leveled within tolerance, and the following steps (5) to (12) must be performed:

(5) Bring the gun bore *up* to zero degrees elevation.

(6) With the gunner's quadrant set to read zero mils on the sight bracket quadrant seat, center the level bubble by adjusting the parallel link.

(7) Elevate the gun bore to 90° and with the quadrant, check the number of mils the computing box is off level. If the error in level is in the positive direction, place shims under the front of the parallel link bracket on the gun trunnion. If the error is negative, place shims under the rear of the same bracket. For each mil of error, place approximately 0.003 thickness of shim under the proper side of the bracket.

(8) Return the gun bore to zero elevation, and again with the quadrant set to read zero mils on the sight bracket quadrant seat, center the quadrant level bubble by the parallel link adjustment.

(9) Again elevate the gun bore to 90° and check the level of the computing box. If not level, repeat step (7) above, adding or subtracting shims.

(10) Then repeat steps (8) and (9) above.

(11) Continue this procedure until the computing box is level at both 0° and 90°.

(12) Elevate the gun bore to 15°, 30°, 45°, 60°, and 75°, in turn, and record the reading of the gunner's quadrant on the sight bracket quadrant seat at each test position. Any

deviations from level should now be within the ± 2 mils tolerance. If not, repeat the entire procedure until the computing box is level within tolerance.

93. Adjustments to Obtain Hit

In computing sight fire control, if the lead setter is able to make definite tracer sensings, adjustments can be made.

a. Line.

(1) *Crossing courses.* If the tracers are high, the lead setter turns the head of the target course arrow away from himself; if the tracers are low, he turns the head of the arrow toward himself.

(2) *Alternate method.* Line adjustments may also be made on crossing courses by adjusting the angle of climb or dive with the arrow adjusting knobs or with the bail. If the tracers are high, the head of the arrow is moved down; if the tracers are low, the head of the arrow is moved up.

(3) *Low angular height.* Line may be adjusted on crossing courses by either of the above procedures. At low angular heights of the gun bore, a more effective adjustment will be obtained by using the change in climb or dive. However, the judgment and experience of the lead setter will determine which adjustment should be used.

(4) *Incoming or outgoing courses.* If the tracers are right, the lead setter turns the head of

the arrow left; if the tracers are left, he turns the head of the arrow to the right.

b. Lead. If the tracers are ahead, the lead setter decreases speed; if the tracers are astern, he increases speed. To adjust on a target flying directly at the gun, speed is zeroed, the position of the target course arrow ignored, and firing continued. Necessary corrections are then obtained by tracking off.

CHAPTER 13

ANTIAIRCRAFT ARTILLERY AUTOMATIC WEAPONS SURFACE FIRING

Section I. GENERAL

94. General

Antiaircraft artillery automatic weapons may be assigned a surface mission against ground or naval targets which may be engaged by either direct or indirect fire. Direct fire is used for rapid engagement of surface targets which are visible to the trackers of the weapon. Indirect fire from defiladed positions is used whenever possible to engage targets which cannot be seen or laid upon effectively through the direct fire sights of the weapon. This method is preferred primarily because it affords protection of personnel and equipment. The AAA (AW) best suited for surface fire is the twin 40-mm gun M42. The multiple caliber .50 M16A1 is less accurate and more difficult to lay in azimuth and elevation, but is equipped with azimuth and elevation scales suitable for either direct or indirect fire.

95. Aimed Fire

There is one important difference between the determination and analysis of firing data for surface fire and that established for AAA fire. In surface fire, a hit is expected with each round, including the initial round fired; opposed to the premise in AA fire that round for round hits are not expected because of the gunnery problem involved.

96. Basic Elements of Data

Regardless of the method or devise used in surface fire, there are certain basic elements of firing data which are present in the gunnery problem.

a. Direction, Gun to Target. Alining the axis of the gun bore in the same vertical plane containing the target and gun is performed either visually or with instruments.

b. Angle of Site. This is the vertical angle between the horizontal plane and the gun-target line, corresponding to E_p, the future angular height in the antiaircraft artillery automatic weapons problem. It can be measured by inspection or estimation, from a map, by surveying instruments, or boresighting on the target and measuring the gun bore elevation with a gunner's quadrant.

c. Range, Gun to Target. This is the distance, in yards, from gun to target. In AAA (AW), this range is horizontal. Range determination is necessary in order to apply superelevation which corresponds to the sum of the field artillery terms "firing table elevation" and "complementary angle of site." Range is normally estimated or taken from a map to the nearest 100 yards.

d. Description. The automatic weapon gun crew should know the type of target to be fired upon in order to select the proper type of ammunition for maximum lethality, and to determine whether to fire area or precision fire. The dimensions of the target also aid in range determination with binoculars with mil scale reticles (see FM 6–40).

Section II. DIRECT FIRE

97. General Procedure

Since direct fire is engagement of targets within view of the enemy and with limited defilade, this precludes deliberate, time consuming methods of gun laying. The weapon must be fired as rapidly as possible and displaced to avoid counterfire.

a. Azimuth. The vertical sight reference line (vertical cross-hair or imaginary vertical line through the center of the sight) must be laid on center of mass of a stationary target, or somewhere ahead of a moving target.

b. Elevation. The horizontal sight reference line (horizontal cross-hair or imaginary horizontal line through the center of the sight) must be laid on center of mass, above, or below the target. In order to determine how much above or below the target the horizontal sight reference line is laid, the angle of site and superelevation must be estimated (fig. 45).

(1) *Angle of site.* During the majority of AAA (AW) direct fire missions, the angle of site will *not* be measured, due to the limited time available. If the target is within 20° of the same level with the firing weapon, the angle of site at a given range will not cause a significant change in ϕ_s. Normally, the angle of site plus generated ϕ_s is automatically determined when the sights are laid on the target. If, however, sufficient time is available to deliberately lay the gun, the direct command procedure (par. 107) or quick quadrant measurement of the angle of site can be used. Utilizing the

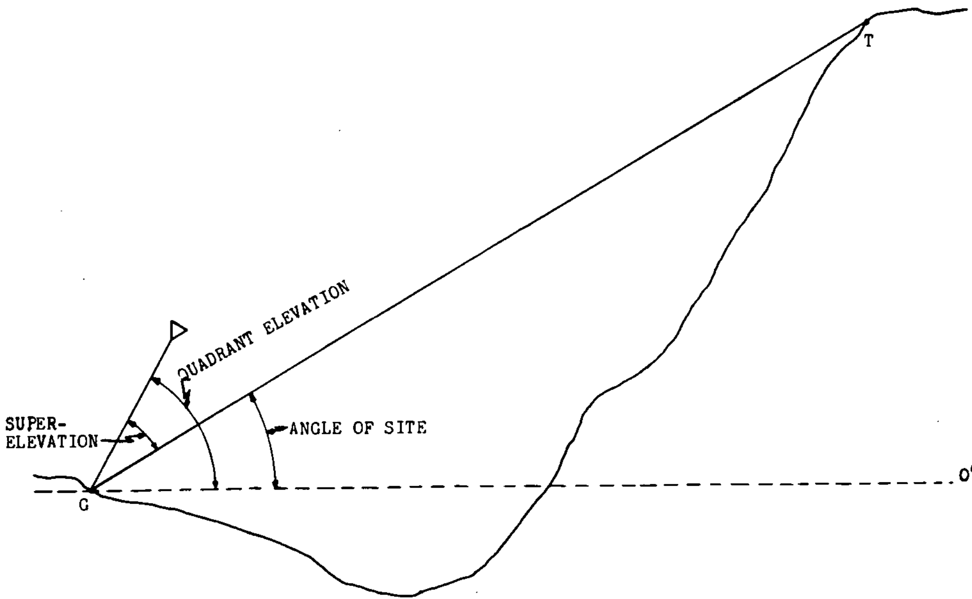


Figure 45. Angle of site, snperelevation and quadrant elevation.

sighting device oriented for AA fire, track the horizontal sight reference line onto the target and measure the quadrant elevation. This quadrant elevation will not be the angle of site, however, since the gun bore will be at an elevation (9 or 10 mils) above the tracker's line of sight. To determine the true angle of site, subtract the 9 or 10 mils (the amount of superelevation oriented into the sight) from the measured quadrant elevation.

(2) *Superelevation.* Normally in direct fire, the 9 or 10 mils superelevation generated by the sight is used as a means of estimating the application of correct superelevation. With the knowledge that the superelevation generated by the M38 computing sight, for example, is 9 mils for a fixed range of 1,160 yards, the horizontal sight reference line would be properly laid above center of mass of the target if estimated range to the target were greater than 1,160 yards; or below center of mass with ranges less than 1,160 yards. The generated superelevation of 10 mils with the M18 speed ring sight is correct for 1,080 yards range. Time permitting, the required superelevation to hit the target may be determined by entering the tabular firing tables or GFT with angular height and particular range to the target as arguments. Algebraically add the required superelevation to the angle of site and set the amount on the gunner's quadrant. Place the quadrant on the

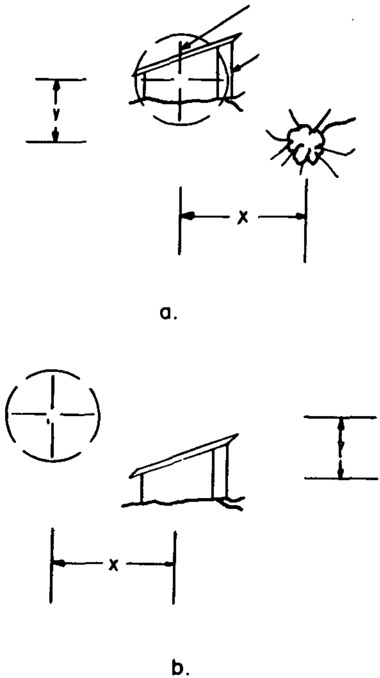
breech casing of the gun and elevate or depress the gun tube until the quadrant level bubble is centered. Direct fire can be used on targets up to 1,500–2,000 yards range.

98. Specific Methods

a. Stationary Targets.

(1) *Computing sight M38.* Manual control is used for stationary surface targets. After speed is zeroed the azimuth tracker uses the M38 metal speed ring sight, and manually alines the vertical sight reference line on center of mass of the target. Adjustments for deviations in azimuth are made by using the splash or burst as a reference for moving the gun according to deviations observed by the azimuth tracker. For example, the azimuth tracker tracks off, moving the point of burst located in the sight (with reference to the vertical sight reference line) onto the target (fig. 46). Adjustments are continued until fire for effect is ordered. In elevation, the elevation tracker should use the reflex sight M24C, if mounted, instead of the metal speed ring sight. The angle of site and superelevation are applied by tracking center of mass of the target with the horizontal sight reference line; then modifying this setting according to target range, by tracking higher or lower. Range deviations are corrected by the splash-on-target method of adjustment, i. e., the elevation

tracker tracks off, moving the point of burst located in the sight (with reference to the horizontal sight reference line) onto the target (fig. 46). Adjustments are con-



a. SIGHT PICTURE WHEN FIRST SPLASH IS OBSERVED
b. SIGHT PICTURE AFTER PROPER ADJUSTMENT

Figure 46. Splash-on-target adjustment.

tinued until correct, then fire for effect is ordered.

(2) *Speed ring sights.* For all speed ring sights, the tracker(s) alines the vertical sight reference line on center of mass of the target. The horizontal sight reference line is laid on center of mass, high, or low on the target, depending on range. Corrections for right and left deviations and for range are made by the splash-on-target method.

b. Moving Targets.

(1) *Computing sight M38.* The speed knob is set at zero and the course arrow disregarded. The azimuth tracker tracks the vertical sight reference line in the metal speed ring sight a specified amount ahead of the target, depending on estimated speed. The average initial lead is one apparent target length ahead of the leading portion of the target. The elevation tracker, using the reflex sight M24C, considers the present superelevation of the sighting device and tracks with the horizontal sight reference line high, low, or center of mass on the target, depending on range. Both trackers adjust by tracer observation or splash-on-target.

(2) *Speed ring sights.* In utilizing speed ring sights on moving surface targets, manual or aided tracking may be used. The tracker(s) tracks off in both azimuth and elevation, depending on range and speed of the target. Adjustments are made by tracer observation or splash-on-target.

Section III. INDIRECT FIRE

99. Employment

The following paragraphs refer only to the self-propelled twin 40-mm gun M42. However, the same general procedures and techniques apply to other light AAA (AW). When using indirect fire techniques in a surface mission, 40-mm guns are normally employed by platoon (4 weapons—8 barrels). A platoon fire direction center is located at or near the position area. 40-mm guns are also employed using the direct command or tank azimuth procedures with no FDC (Fire Direction Center) which is discussed in paragraphs 105 through 107.

100. Emplacement

a. Due to the flat trajectory of the 40-mm projectile, gun positions must be carefully selected to secure the maximum defilade and still provide the desired target area coverage. To obtain the correct density of fire on all targets, it is desirable that guns be emplaced about 20 yards apart so they can apply a parallel sheaf 60 yards in width. However, the tactical situation may often require that weapons be dispersed at a greater interval. If this results in a platoon front greatly in excess of 60 yards, corrections are applied at the time the platoon is oriented to reduce the width of the sheaf (par. 104).

b. No matter how the weapons are numbered within the platoon, guns in a surface-firing position are normally numbered from right to left, facing the direction of fire.

c. Gun carriages should be cross-leveled, when time permits, to eliminate errors produced by cant.

The level may be checked by using the gunner's quadrant on the two sets of quadrant seats (set at right angles to one another) located on the left pedestal of the M42.

101. Calibration

a. Within the battalion, gun barrels should be calibrated and barrels having similar shooting characteristics should be grouped together within each platoon and on each mount (FM 6–40). This calibration should be conducted with instruments initially by ordnance personnel. To supplement this, or if no ordnance calibration is possible, the battery should make a comparative calibration by firing. However, as no firing table data are available from which a VE (velocity error) may be computed, the relative shooting qualities of various barrels are determined by a comparison of corrections (K's) in yards per thousand yards of range. Using the average range of all centers of impact as standard, barrels are grouped according to their variation from that standard as expressed by a plus or minus K.

b. Within the platoon, the longest-shooting barrels should be used on the base piece because additional firing of that weapon will tend to reduce their muzzle velocities faster than other weapons of the platoon. Calibration should be repeated as a check on subsequent barrel wear and barrels should be regrouped if necessary.

102. Orientation in Elevation

Since each round is aimed in elevation with a gunner's quadrant, no orientation in elevation is required. Quadrant seats are provided on the breech casing of the left gun.

103. Orientation in Azimuth

Self-propelled twin 40-mm guns are laid for direction by means of azimuth indicators. The M42 has a clock-type azimutb indicator graduated in mils from zero to 6,400. For a more complete description of the azimuth indicator, see TM 9–761A and FM 44–61. There are two methods of orienting the guns using the azimuth indicator.

a. Known Datum Point Method. Bore sight the left barrel of the gun by traversing to the known datum point. Without moving the gun, set the azimuth to that of the known datum point on the azimuth indicator, using the resetter knob.

b. Backsighting Method. In order to employ this method, an aiming circle must be available. Set up the aiming circle at least 60 yards from the guns; orient it with reference to grid north, using the compass needle of the aiming circle or surveyed orienting line (FM 6–140). Bore sight the left barrel of the gun on the aiming circle by traversing it until the axis of the bore coincides with the optical center of the aiming circle. With the azimuth knob (upper motion), turn the line of sight of the aiming circle onto the axis of the bore of the gun barrel. When the axis of the bore of the barrel and the line of sight of the aiming circle coincide, the back azimuth of the angle on the aiming circle is set on the azimuth indicator as described in *a* above. When each gun in the platoon has been oriented in a similar manner and the same azimuth has been set off on the azimuth indicator, the gun barrels will be parallel.

104. Adjusting the Sheaf of a Platoon

If the width of the sheaf of a platoon is too great for proper target area coverage (par. 100*a*), it may be adjusted to an effective width by announcing special corrections in azimuth to each of the guns after orientation. The platoon commander determines by the mil relation the number of mils in azimuth each gun must shift to close or open the sheaf to form a 60-yard sheaf at a range of 3,000 yards. A range of 3,000 yards is chosen arbitrarily as one which will cause a sheaf of optimum effectiveness to be formed at ranges customarily used. This shift is computed by determining the difference between the existing weapon interval and the desired interval (20 yards) for a 60-yard sheaf. This difference in yards is converted to mils at 3,000 yards range, using the mil relation. Each weapon, except the base piece, is traversed toward (or away from) the base piece the required number of mils. Without changing the positions of the barrels, the azimuth indicators of these pieces are then reset to their previous reading.

Example:

a. Computation of Shift.

Platoon front	105 yards
Base piece	Gun No. 2
Interval between guns 1 and 2	35 yards
Desired interval (60÷3)	20 yards
Difference	15 yards
15÷3.0=5 mils	
Interval between guns 2 and 3	30 yards
Desired interval	20 yards
Difference	10 yards
10÷3.0=3.3 or 3 mils	
Interval between guns 2 and 4	70 yards
Desired interval	40 yards
Difference	30 yards
30÷3.0=10 mils	

b. Application of Shift. Guns have been oriented and laid parallel at azimuth 1,800 mils.

(1) No. 1 gun traverses to the *left* 5 mils (A_z 1,795) and resets azimuth indicator at 1,800.

(2) No. 2 gun, the base piece, does not change.

(3) No. 3 gun traverses to the *right* 3 mils (A_z 1,803) and resets azimuth indicator at 1,800.

(4) No. 4 gun traverses to the *right* 10 mils (A_z 1,810) and resets azimuth indicator at 1,800.

105. Observer Procedure—General

Two methods of bringing fire on targets by the commands of an observer may be employed.

a. Target Grid Procedure.

b. Direct Command Procedure.

106. Target Grid Procedure

This is the observer procedure described in FM 6–40. It is the normal procedure employed with all AAA weapons in indirect surface firing.

107. Direct Command Procedure

a. General. This method is intended primarily for use with self-propelled light AAA (AW) firing from the protection of defiladed positions. It provides a rapid, accurate means of placing fire on targets at ranges beyond the effective vision (approximately 1,500 yards) of on-carriage sights or when visibility from the guns is reduced by dust, smoke, defilade, or other causes. It is suitable for use primarily with single weapons where a fire direction center is not available. However, with proper coordination, it may be used to fire a platoon or battery.

b. Limitation. Direct command procedure can best be used when the displacement of the observer from the gun position in any direction is less than one-tenth of the gun-target range (fig. 47). The observer may transmit his commands direct to the gun without resorting to the use of a fire direction center, as in target-grid procedure. However, if the observer is located at a greater distance than this from the guns, target-grid procedure is preferable. If it is apparent that more than one target is to be

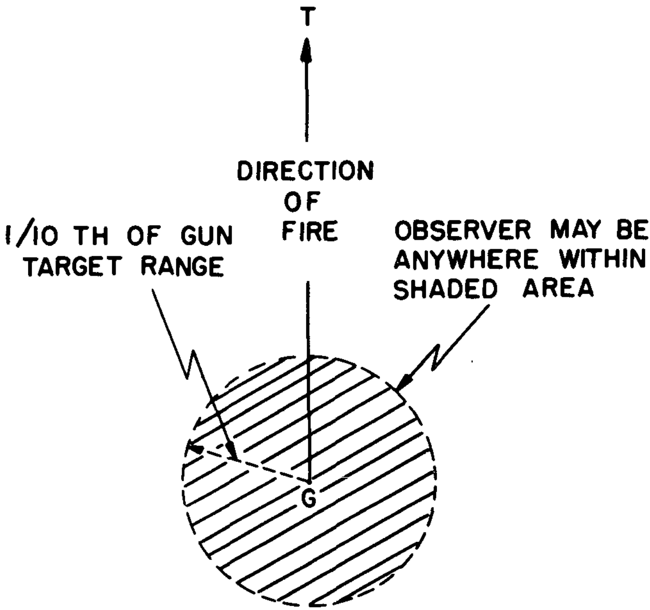


Figure 47. Displacement of observer from gun position.

engaged from any one position, the observer should select an observation point so that his lateral location from the gun is less than one-tenth of the gun-target range to the most critical target.

c. Initial Data. The squad leader of the self-propelled AAA (AW) weapons is normally the observer. Upon entering a surface (indirect) firing position, he determines certain initial data which are necessary to orient the weapon and to place initial rounds on or near the target.

(1) *Orientation.* The squad leader selects a terrain feature which is visible from the gun as a reference point. He determines the approximate azimuth from the gun to the reference point by means of a map or compass, or he may assume an arbitrary azimuth for this direction line (par. 108). The weapon is oriented in azimuth by the trackers alining the barrels on the reference point and setting the azimuth to that point on the azimuth indicator.

(2) *Initial firing data.* From his observation post near the gun, the observer determines initial data in azimuth and range which will place initial rounds on or near the target.

(*a*) *Azimuth.* The observer determines the azimuth to the target by use of a compass, or by measuring the angle between the reference point ((1) above) and the target with binoculars or any suitable angle-measuring device. The initial azimuth is announced to the gun as AZIMUTH (so much) in mils.

(*b*) *Site.* The difference in altitude between the gun and target is normally estimated or scaled from a map. This difference in altitude, in yards, is converted to a vertical angle in mils by use of the mil rule. If an angle-measuring instrument is available, the angle of site may be measured directly. This is announced to the gun as SITE PLUS (MINUS) (so many) MILS.

d. Sequence of Fire Commands. Initial fire commands are transmitted in the following sequence:

Note. Fire commands used in the direct command procedure using only one piece are indicated with an asterisk (*).

Sequence	*Example*
(1) *Pieces to follow commands.*	NO. 1, ADJUST.
(2) *Projectile*	SHELL HE.
(3) *Pieces to fire*	(Omitted where the pieces to fire are the same as the pieces to follow commands).
(4) *Method of fire**	ONE ROUND (on twin-gun mounts, this command may be preceded by the designation of a single barrel to fire, e. g., RIGHT (LEFT) BARREL, ONE ROUND. If no mention is made of barrels, each barrel will fire the designated number of rounds).
(5) *Direction**	AZIMUTH 1,800.
(6) *Site**	SITE PLUS 8.
(7) *Range**	RANGE 4,000.

e. Application of Initial Fire Commands at the Gun. The initial fire commands of the observer are applied to the weapon in the following manner:

(1) The first four commands serve to alert the

crew and designate the ammunition to be used.

(2) The command for azimuth is transmitted to the azimuth tracker, who traverses the weapon to the announced azimuth.

(3) The commands for site and range are transmitted to the quadrant setter. From a GFT (graphical firing table), the quadrant setter determines the elevation corresponding to the announced range. He adds the angle of site algebraically to this elevation and sets the resulting sum on the gunner's quadrant. When the quadrant bubble has been leveled, he gives the command FIRE.

f. Subsequent Corrections. The observer adjusts the fire of the gun on the target by sending corrections for subsequent rounds directly to the guns. Shots which are off the observer-target line are brought to that line by commanding a shift in the appropriate direction in mils, e. g., RIGHT (LEFT) 5. The target is bracketed for range, using normal observer procedure, by commanding changes in range in yards, e. g., ADD (DROP) 400. The initial range change should be large enough to insure bracketing the target. This bracket is successively split until the target is within a bracket of suitable size, depending on the nature of the target. Fire for effect is begun at the center of that bracket. It should be noted that at ranges up to 4,000 yards the fragmentation effect of the 40-mm projectile is mainly forward of the point of impact with some side spray and a negligible amount of base spray. Therefore, when firing at less than 4,000 yards, fire for effect is normally placed short of the center of the target. Corrections are announced in the following sequence:

Sequence	*Example*
(1) *Change in ammunition*	SHELL AP.
(2) *Change in method of fire:* for example, to change the number of rounds upon entering fire for effect or to change from single barrel to twin barrels to facilitate sensing.	10 ROUNDS, (or BOTH BARRELS).
(3) *Deviation correction*	RIGHT 10.
(4) *Range correction*	DROP 50.

Note. Subsequent corrections are always terminated with a correction for range. Any element which is not being changed may be omitted, except range; if no change is desired in range, the observer sends REPEAT RANGE.

g. Application of Subsequent Corrections at Gun.

(1) When a change in azimuth is announced by the observer, the azimuth tracker traverses the gun until the new azimuth is set on the azimuth indicator. The azimuth tracker must bear in mind that azimuths decrease when moving to the left and increase when moving to the right. For example, a shift of RIGHT 60 from an azimuth setting of 1,367 would result in a new setting of $1,367+60=1,427$. A subsequent command of LEFT 35 would change the setting to $1,427-35=1,392$.

Note. The gunner's aid dial (outer dial) of the azimuth indicator is used as an aid in the computation of new azimuths (fig. 48). For complete instructions on the use of the azimuth indicator and the gunner's aid dial, see FM 44–61.

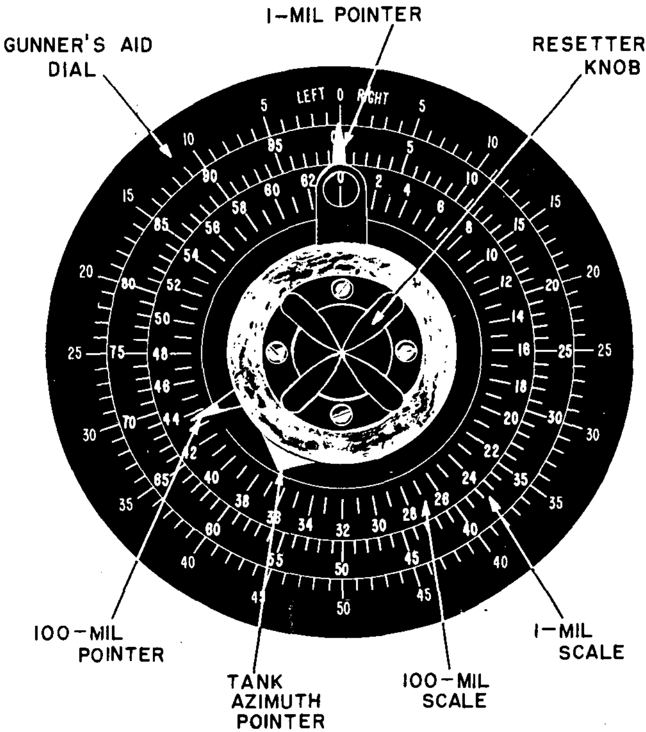


Figure 48. Gunner's aid dial.

(2) In handling subsequent corrections in range, the quadrant setter uses the *c* (number of mils elevation equivalent to a 100-yard change in range) corresponding to the initial range command. The value of *c* in mils is taken from a graphical firing table. The quadrant setter multiples *c* by the range correction expressed in hundreds of yards. He adds the resulting value in mils algebraically to the last quadrant fired.

For example, assume a round was fired at a quadrant of 70 and that $c=3$ mils. If a range change of ADD 400 were ordered, the quadrant setter would set his quadrant at $70+3\times4=82$. A subsequent correction of DROP 200 would result in a quadrant setting of $82-3\times2=76$.

108. Direct Command Procedure Using Tank Azimuths

The use of assumed tank azimuths provides a rapid and effective means of preparing initial data and orienting self-propelled weapons for firing, using direct command procedure. This method is especially applicable to situations where neither the time nor the means are available to determine grid azimuths. To employ tank azimuths, the azimuth indicator of the weapon is set at zero with the guns locked in the forward traveling position. Tank azimuths are clockwise angles measured from the center line of the vehicle with the front of the vehicle assumed to be zero azimuth (fig. 49). The observer uses the direction in which the vehicle is pointing as a basis for computing tank azimuths to targets. If time is available before the weapon occupies position, the observer selects a reference point toward which the driver will point his vehicle upon moving into position. This reference point is assumed to have an azimuth of zero mils and an approximate orientation on this assumed azimuth is accomplished when the vehicle is lined up on this point. The observer determines the tank azimuth to the target by measuring directly from the reference point. Before the weapon has occupied position, the driver has the reference point identified to him and the

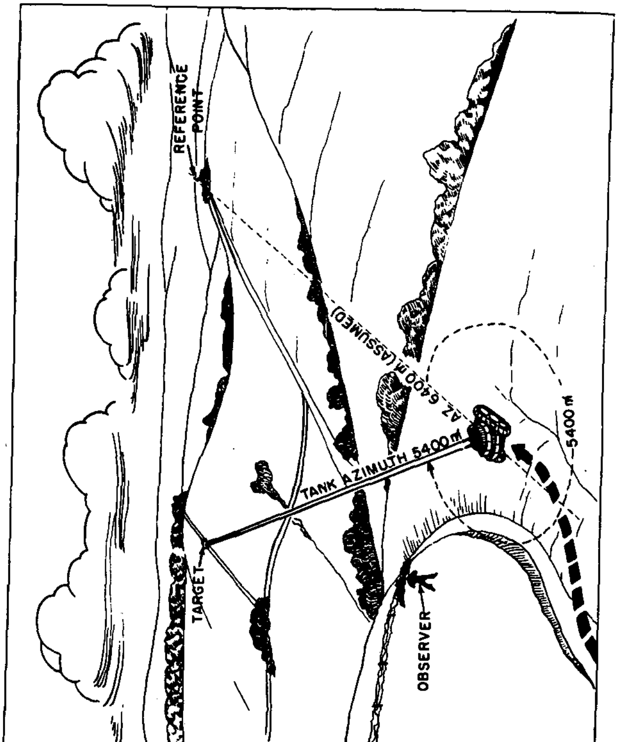


Figure 49. Tank azimuths used with direct command procedure.

crew is given sufficient data to enable the initial round to be fired immediately upon occupying position. These data should include:

a. Shell.

b. Method of fire.

c. Tank azimuth to target.

d. Angle of site.

e. Initial range.

109. Illustrative Example, Direct Command Procedure

Area fire mission; target, machine gun position; mission, neutralization; materiel, one 40-mm weapon (M42). The weapon has been oriented on a reference point with an approximate azimuth. The observer is 120 yards to right of the gun position. He estimates azimuth to target as 1,800 mils. Range to target is estimated at 4,000 yards and difference in altitude is + 30 yards. Angle of site is therefore $30 \div 4 = +8$. The tabulated illustrative example is as follows:

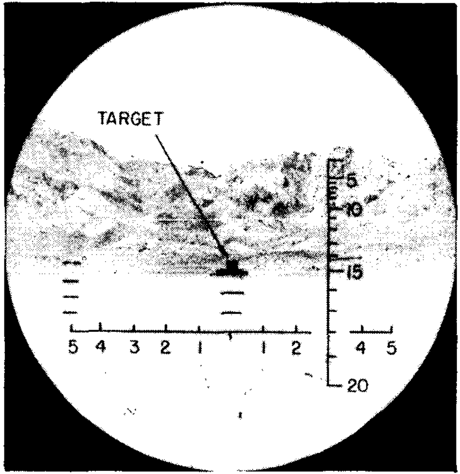
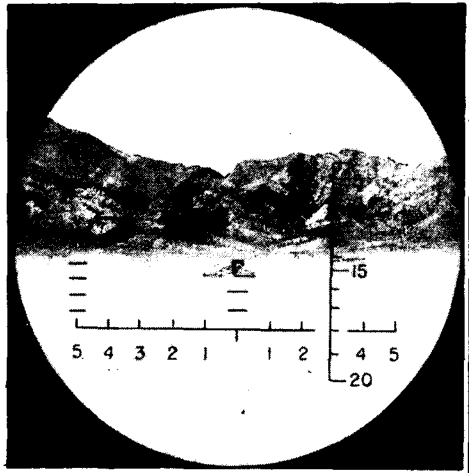
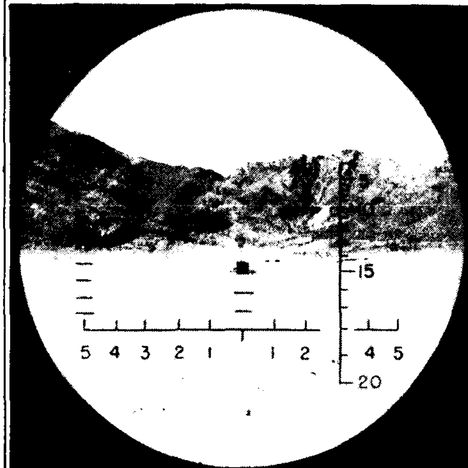
<table>
<tr><th rowspan="2">Commands</th><th rowspan="2">Results</th><th colspan="2">Sensings</th></tr>
<tr><th>Rn</th><th>Dev</th></tr>
<tr><td>Observer to gun:
NO. 1 ADJUST, SHELL HE, ONE ROUND, AZIMUTH 1,800, SITE PLUS 8, RANGE 4,000.
Action of gun crew:
Azimuth tracker: traverses until 1,800 appears on azimuth indicator.
Quadrant setter: determines elevation (62) for 4,000 yards range from GFT. Notes value of c is 3 mils. Adds angle of site of 8 mils and sets result (70) on quadrant. When quadrant bubble is level, commands FIRE.</td><td>

Figure 50. First volley.</td><td>(?) (doubt-ful)</td><td>45L</td></tr>
</table>

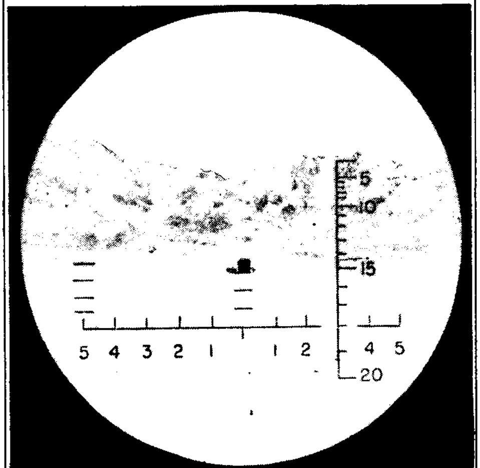
Remarks. Inasmuch as no mention was made of barrels to fire, both barrels of the weapon fire.

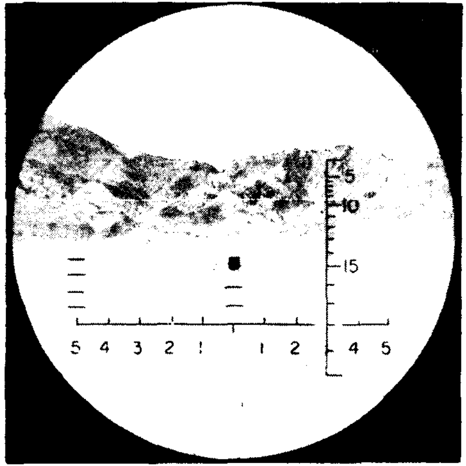
Observer to gun: RIGHT 45, REPEAT RANGE. *Action of gun crew:* Azimuth setter: adds 45 to 1,800, sets 1,845 on azimuth indicator. Quadrant setter: fires piece at Q70.	 *Figure 51. Second volley.*	(—) (short)	Line

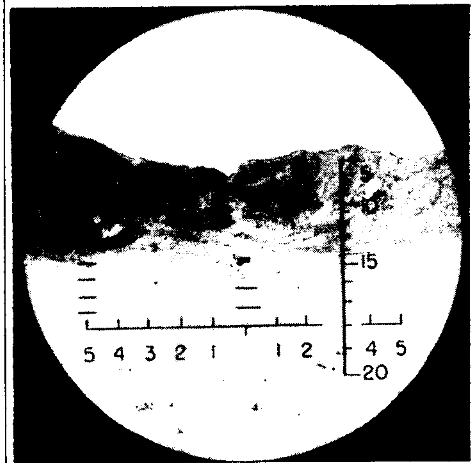
Remarks. Initial data estimated. Observer decides a range change of 400 yards will establish a bracket.

Commands	Results	Sensings	
		Rn	Dev
Observer to gun: ADD 400. *Action of gun crew:* Quadrant setter: multiplies range change (in hundreds of yards) by equivalent elevation (*c*), $4 \times 3 = 12$. Adds results to last quadrant setting, $12 + 70 - = 82$, and sets quadrant and fires piece at Q82.	 *Figure 52. Third volley.*	(+) (over)	5R

Remarks. Small deviation is caused by the target offset (30 mils). Observer elects to ignore it unless it persists inasmuch as he is able to obtain range sensings.

Observer to gun: DROP 200. *Action of gun crew:* Quadrant setter: computes new quadrant setting. $-2\times 3=-6$; $82-6=76$. Fires piece at Q76.	 *Figure 53. Fourth volley.*	(+) (over)	2R

Commands	Results	Sensings	
		Rn	Dev
Observer to gun: DROP 100. *Action of gun crew:* Quadrant setter: $-1\times3=-3$; $76-3=73$; Piece is fired at Q73.	 *Figure 54. Fifth volley.*	(−) (short)	Line

Observer to gun: 5 ROUNDS, ADD 50. *Action of gun crew:* No. 4: prepares 5 rounds of ammunition for each barrel. Quadrant setter: $.5 \times 3 = 1.5$. $73 + 1.5 = 74.5$. Piece is fired at Q74.	 *Figure 55. Sixth volley.*	Correct	Line

Remarks. Fire effectively covers area and machine gun appears to be silenced. Observer sends to gun, END OF MISSION, MACHINE GUN NEUTRALIZED.

APPENDIX I

REFERENCES

DA Pam 108–1	Index of Army Motion Pictures, Television Recordings, and Filmstrips.
DA Pam 310–5	Index of Graphic Training Aids and Devices.
DA Pam 310-series	List of Training Publications.
SR 320–5–1	Dictionary of United States Army Terms.
SR 320–50–1	Authorized Abbreviations.
AR 385–63	Regulations for Firing Ammunition for Training, Target Practice, and Combat.
FM 3–5	Tactics and Technique of Chemical, Biological, and Radiological Warfare.
FM 5–15	Field Fortifications.
FM 5–35	Engineers' Reference and Logistical Data.
FM 6–40	Field Artillery Gunnery.
FM 7–15	Heavy Weapons Company, Infantry Regiment.
FM 7–20	Infantry Battalion.
FM 7–40	Infantry Regiment.
FM 8–5	Medical Department Units of a Theater of Operations.
FM 8–10	Medical Service, Theater of Operations.

FM 20–32	Employment of Land Mines.
FM 21–5	Military Training.
FM 21–30	Military Symbols.
FM 21–40	Defense Against CBR Attack.
FM 21–41	Soldiers Handbook for Defense Against CBR Attack.
FM 21–48	CBR Training Exercises.
FM 25–10	Motor Transportation, Operations.
FM 30–30	Aircraft Recognition Manual.
FM 31–15	Operations Against Airborne Attack, Guerilla Action, and Infiltration.
FM 31–50	Combat in Fortified Areas and Towns.
FM 44–1	Antiaircraft Artillery Employment.
FM 44–8	Antiaircraft Operations Center and Antiaircraft Artillery Information Service.
FM 44–57	Service of the Piece, Multiple Caliber .50 Machine-Gun Motor Carriage M16 and Multiple Caliber .50 Machine-Gun Motor Carriage M55.
FM 44–61	Self-Propelled Twin 40-mm Gun T141.
FM 100–5	Field Service Regulations, Operations.
FM 100–10	Field Service Regulations, Administration.
FM 100–11	Signal Communications Doctrine.

FM 101–10	Staff Officers' Field Manual, Organization, Technical, and Logistical Data.
TM 9–761A	Self-propelled Twin 40-mm Gun M42 T141.
TM 44–234	Antiaircraft Artillery Service Practice.
ATT 44–3	Antiaircraft Artillery Automatic Weapons Battalion (Self-Propelled).
ACP 125	Joint Communications Instructions, Radiotelephone Procedure.
JANAP 164	Joint Radiotelephone Procedure for the Conduct of Artillery and Naval Gunfire.

APPENDIX II

ANTIAIRCRAFT ARTILLERY (AUTOMATIC WEAPONS) TRAINING AIDS

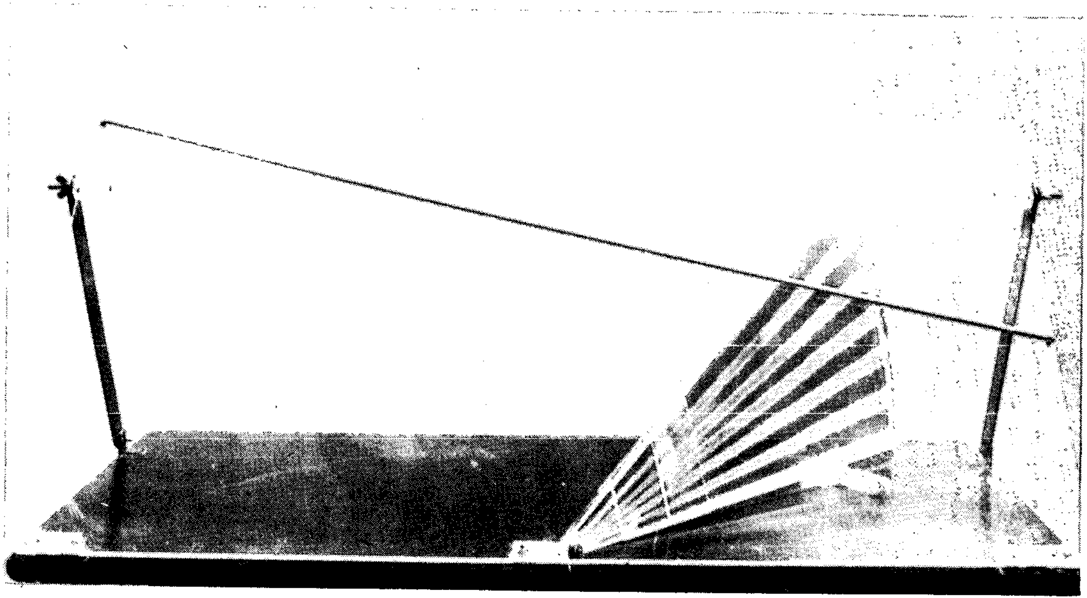


Figure 56. Slant plane and angular height fan. Made of ½″ clear sheet plastic. The fan illustrates variations in angular height. Target course rod is ¼″ in diameter. The aid is mounted on sheet plywood.

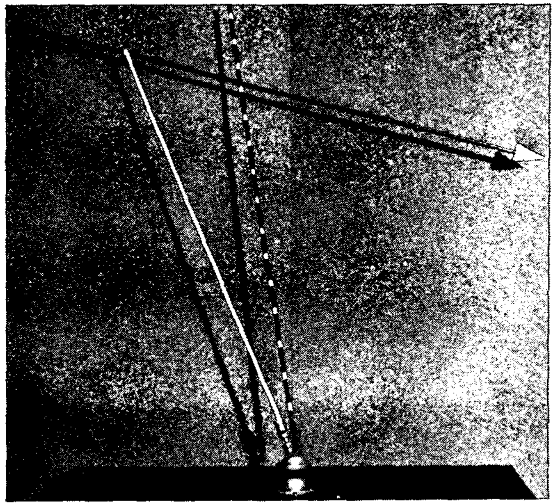


Figure 57. LAAA (AW) problem aid. The rods depicting D_o, D_p, and target course line are 3/8″ diameter, painted white and red. Ball and socket joint is screwed to a sheet of plywood.

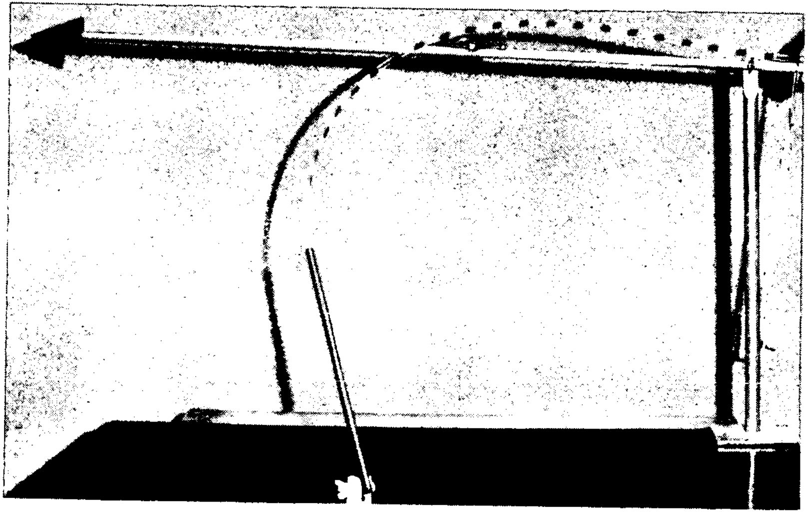


Figure 58. Tracer observation aid. The gun is a 3/8'' metal tube. Target course line is a 3/8'' metal rod, fastened to a 1/2'' rod screwed to plywood base. Thin strip of plastic painted with red slashes depicts tracer path and illustrates illusion of curvature.

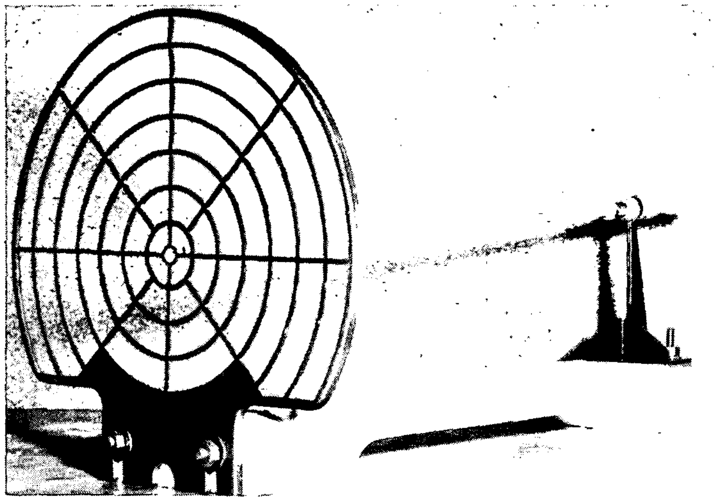


Figure 59. Speed ring aid. Front and rear elements of standard speed ring sight are bolted to a board. Wooden pointer passes through rear element to illustrate line of sight.

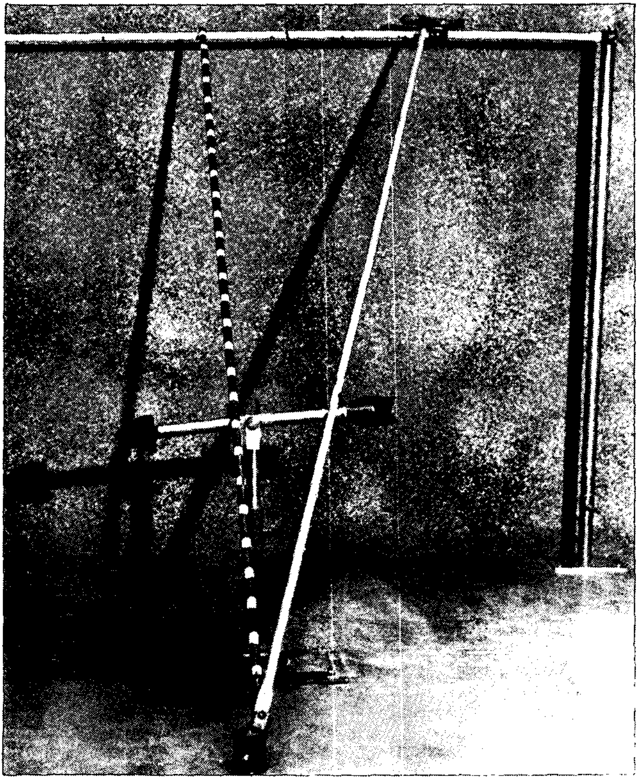


Figure 60. Computing sight aid. Made of ⅜″ rods painted red and white. Model aircraft slides on target course rod. D_o and D_p rods pivot at base. Target course arrow moves in all directions.

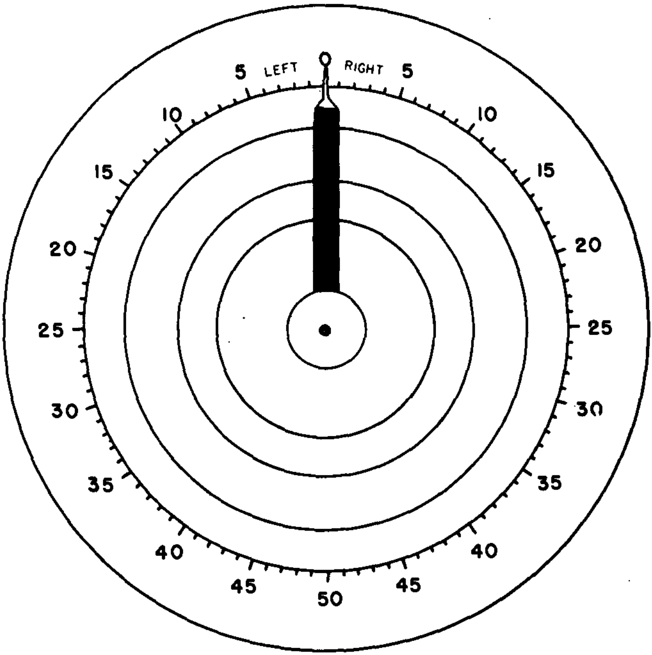


Figure 61. Azimuth indicator aid. Mounted on heavy cardboard, the indicator arm and center pivot are wood and are painted black. Dial is drawn on face of cardboard.

APPENDIX III

MATHEMATICAL ANALYSIS OF LEAD

1. Analysis of Required Lead Equation

$$Sin\ L_R = V \frac{t_p}{D_p} Sin\ \alpha$$

This equation means that the sine of the required lead angle (sin L_R) is the product of: target speed (V) in yards per second; the quotient of a value for slant range divided into its corresponding value of time of flight $\left(\frac{t_p}{D_p}\text{, the range factor}\right)$; and the sine of the angle of approach (*sin* α). These factors will be analyzed individually to determine their effect on the magnitude of the required lead.

a. V (Speed). In order to visualize the effect of varying speed on the value of the required lead, assume that the remaining factors $\left(\frac{t_p}{D_p} \text{ and } sin\ \alpha\right)$ are constant. Assign them values, the origin of which will be seen below, then insert varying speeds into the equation. Assuming a value of 0.00116 for $\frac{t_p}{D_p} \times \sin \alpha$ and $V = 100$, 200, and 400 yd/sec, respectively:

$sin\ L_R = 100 \times 0.00116 = 0.11600$ then; $L_R = 118$ mils
$sin\ L_R = 200 \times 0.00116 = 0.23200$ then; $L_R = 238$ mils
$sin\ L_R = 400 \times 0.00116 = 0.46400$ then; $L_R = 491$ mils

Thus it is clearly shown that by doubling speed, the value of sin L_R is doubled, and for all practical purposes, the magnitude of L_R itself is doubled. Therefore, for all practical purposes, the magnitude of the required lead angle varies directly with the target speed.

b. $\frac{t_p}{D_p}$ *or Range Factor.* Because of the high muzzle velocity developed by AA (AW), the range factor is almost constant within the effective ranges of antiaircraft artillery automatic weapons sighting devices. Time of flight increases or decreases almost proportionally to range. In order to observe the small variations of the numerical value of this factor, select three future ranges, extract corresponding times of flight from 40-mm firing tables, divide them by the ranges, and compare the resultant range factors:

D_p (yards)	t_p (seconds)	Range factor		
500	0.58	0.00116		
			0.00007	
1,000	1.23	0.00123		0.00016
			0.00009	
1,500	1.98	0.00132		

Between 500 and 1,000 yards the difference is only 0.00007; between 1,000 and 1,500 yards the difference is only 0.00009. Between 500 (a short range) and 1,500 yards (close to maximum effective range of AAA automatic weapons), the variation is only 0.00016. How will this variation affect the magnitude of the required lead? By selecting a speed of 400 mph (200 yds/second) and comparing future ranges of 500 and 1,500 yards, the lead required to hit the target with T_c at midpoint can be computed.

(When T_o is at midpoint, the angle α is 90° and $sin\ \alpha$ is 1.0).

For D_p of 500 yards:	For D_p of 1,500 yards:
$sin\ L_R = 200 \times 0.00116 \times 1$	$sin\ L_R = 200 \times 0.00132 \times 1$
$sin\ L_R = 0.23200$	$sin\ L_R = 0.26400$
$L_R = 238$ m̸	$L_R = 272$m̸

The required lead has changed only 34 m̸ for 1,000 yards change in range; an average of only 3.4 m̸ per 100 yards of range change at midpoint. Since the effect of varying range as expressed by the range factor is so slight, the two types of sighting devices used with AAA (AW) were designed about a fixed value for this factor. This assumption permitted these sights to be simple, light, and rugged, with a relatively small sacrifice in accuracy.

c. Sin α. The angle of approach is always measured from T_o to G and T_p. It is an acute angle on the approaching leg, a right angle at midpoint, and an obtuse angle on the receding leg; varying, in theory, from 0° to 180°. In the required lead equation, use the sine of the angle of approach which varies from 0 to 1 for corresponding values of the angle α. Thus, the effect of sin α as a factor in the required lead equation will be the reduction of the required lead far out on the approaching and receding legs and an increase to maximum at midpoint. Hence, the value of the sine of the required lead angle varies directly with the sine of the angle of approach. Now that the factors of the required lead equation have been analyzed, the required lead and the equation should be used to compare L_G with L_R. This permits an evaluation of different sights and the methods by which they may be put to use.

2. Required Lead Curve

a. The first step in such an evaluation is the preparation of a graphical representation of the required lead throughout a given target course. By assuming a target speed (V) and midpoint range (D_m), a target course and its location in relation to the gun are determined. These are all the facts needed for computing a lead curve, since a slant plane has been established. By selecting sucessive values of D_p and by the trigonometric solution of a series of triangles, a series of values for L_R in mils are computed. These values are plotted against time (in seconds) required for the target to fly from T_o to midpoint. This plot will yield the lead required to make the projectile intersect the center of mass of the target at different locations along the course line. The following are the computations involved in determining points with which to plot a required lead curve, assuming V as 200 yards/second and D_m as 600 yards.

b. Midpoint range and target speed must be assigned for each curve to be computed (fig. 62).

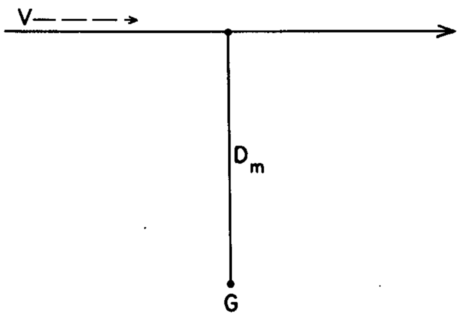


Figure 62. Midpoint range and target speed.

c. A D_p is selected within the maximum effective hitting range of the weapon (fig. 63).

d. Knowing D_p, a corresponding value for t_p may be extracted from firing tables.

e. To obtain distance $\overline{T_oT_p}$, multiply V by t_p. This further locates T_o, α, and L (fig. 64).

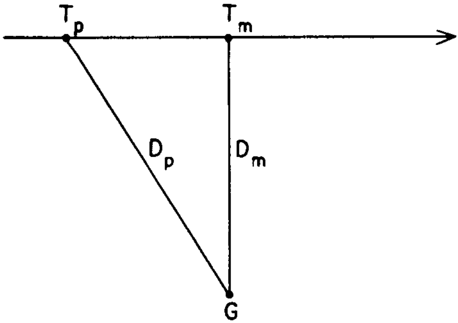


Figure 63. Selected D_p.

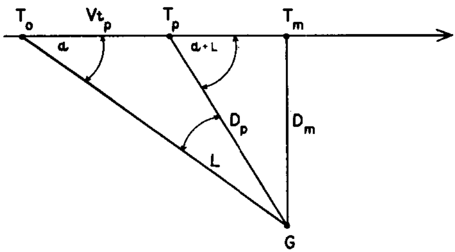


Figure 64. Location of T_o, α, *and* L.

f. The angle GT_pT_m equals $(\alpha+L)$, since it is supplementary to angle GT_pT_o. Therefore, in the right triangle GT_pT_m; $\sin\ (\alpha+L)=\frac{D_m}{D_p}$. Thus the value $(\alpha+L)$, may be found in mils.

g. To determine distance $\overline{T_pT_m}$ (necessary for the solution of triangle GT_oT_m):

$$\text{Tan } (\alpha+L=\frac{D_m}{\overline{T_pT_m}} \text{ or } \overline{T_pT_m}=\frac{D_m}{\tan (\alpha+L)}$$

h. To determine distance $\overline{T_oT_m}$:

$\overline{T_oT_m}=\overline{T_oT_p}+\overline{T_pT_m}$. When T_o is less than t_p seconds from T_m (on the approaching leg only):

$\overline{T_oT_m}=\overline{T_pT_m}-\overline{T_pT_m}$. When T_o is on the receding leg:

$\overline{T_oT_m}=\overline{T_pT_m}-\overline{T_oT_p}$.

i. To determine α:

$$\text{Tan } \alpha=\frac{D_m}{\overline{T_oT_m}}$$

j. Once α has been determined, subtract it from $(\alpha+L)$ to obtain L_R.

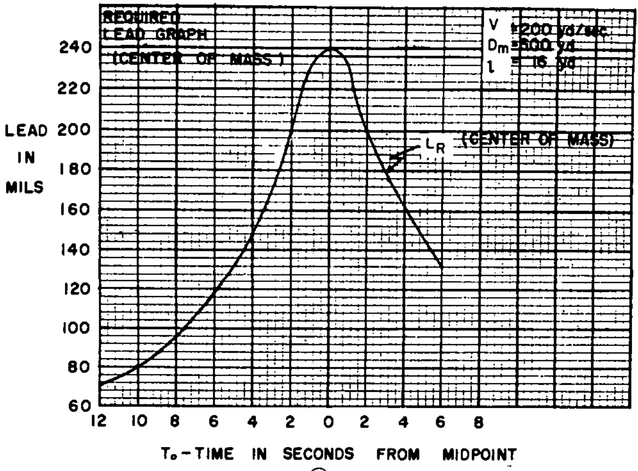
k. To determine the time required for the target to fly from T_o to T_m (the second argument for the plot of the curve); divide distance $\overline{T_oT_m}$ by V to obtain time in seconds from midpoint. Figure 65① is a typical required lead graph to hit center of mass.

l. Figure 65② is the required lead graph for hitting the tail and nose of the same target in figure 65①. To plot these curves, subtract one-half the length (1) of the target (for L_{RT}) and add ½ the length of the target (for L_{RN}).

The formulae for plotting the curves are then:

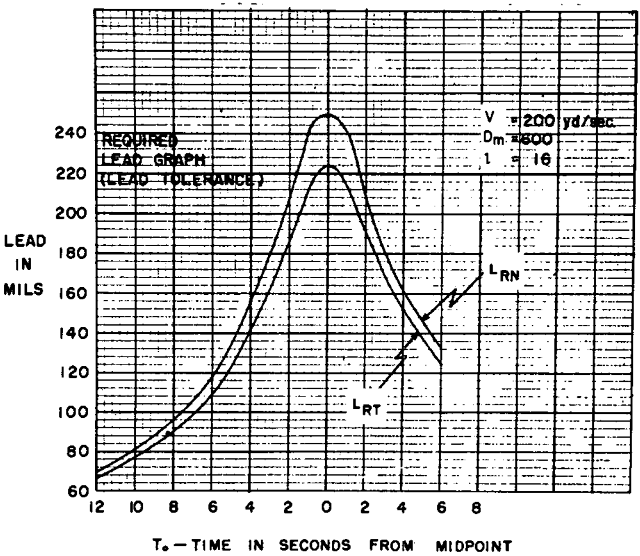
$$\text{Sin } L_{RN}=\left(\frac{V_{tp}+\frac{1}{2}\,1}{D_p \text{ to nose}}\right) \text{Sin } \alpha$$

$$\text{Sin } L_{RT}=\left(\frac{S_{tp}-\frac{1}{2}\,1}{D_p \text{ to tail}}\right) \text{Sin } \alpha$$



①

Figure 65. Required lead graphs.



②

Figure 65.—Continued.

3. Generated Lead Curve

a. General. Each type of sighting device solves the lead problem in a different manner. The lead generated by these devices, however, is based on some variation of the required lead equation. To understand each sighting device more fully and to be able to intelligently analyze the lead performance of a gun crew, the supervising officer should know how the solution of lead of a sight compares with the required lead.

b. Speed Ring Sights. The speed ring sight generates a lead based on an estimated speed, a fixed (F), range factor, and fixed angle of approach. The generated lead equation for speed ring sights is:

$$\sin L_G = V\left(\frac{t_p}{D_p}\right)^F (\sin \alpha)^F$$

D_p for all speed ring sights is 1,000 yards. $(\sin \alpha)^F$ is a constant 1.00, because α is 90°. Assuming a speed of 400 miles per hour, utilizing a 40-mm gun, the equation becomes:

$$\sin L_G = 200 \times \frac{1.23}{1000} \times 1.00 = .2460$$

$$L_G = 253\not{m} \text{ (approx)}$$

If a target traveling 400 mph, and flying a course with a midpoint range of 600 yards, were tracked on the 400 mph speed ring, the lead generated would be too great for the entire course. The rule, however, is to track on the speed ring representing ¾ estimated target speed. The generated lead equation then becomes:

$$\sin L_G = 150 \times \frac{1.23}{1000} \times 1.00 = .1845$$

$$L_G = 189 ⦶ \text{ (approx)}$$

To graphically compare this generated lead with the required lead, draw a line on the line representing 189 ⦶ on figure 65②. It can be seen that the generated lead comes within the required lead curve at only two places. This, however, is better than having the lead too great throughout the entire course, thus the reason for applying the ¾ speed rule.

c. Computing Sights. The computing sight generates a lead based on estimated speed, fixed, (F), range factor, and a variable angle of approach. The generated lead equation for computing sights is:

$$\sin L_G = V\left(\frac{t_p}{D_p}\right)^F \sin \alpha$$

D_p for computing sights is 900 yards.
t_p is a constant 1.09 seconds.
Assuming a speed of 400 miles per hour, at midpoint, utilizing a 40-mm gun, the equation becomes:

$$\sin L_G = 200 \times \frac{1.09}{900} \times 1.00 = .218$$

$$L_G = 224 ⦶ \text{ (approx)}$$

If a target traveling 400 mph, and flying a course with a midpoint range of 600 yards, were tracked with a computing sight speed set at 400 mph and the target course arrow was set parallel to the target course line, the lead generated would be within tolerance (fig. 66). With the generated α changing all along the course, however, the lead would change. Utilizing a target course of 600 yards midpoint range and a speed of 400 mph, it is then possible to solve and plot the generated lead curve for computing sights. By superimposing the L_G curve over the L_R curve for the same course, it is possible to analyze the lead performance of the computing sight (fig. 66).

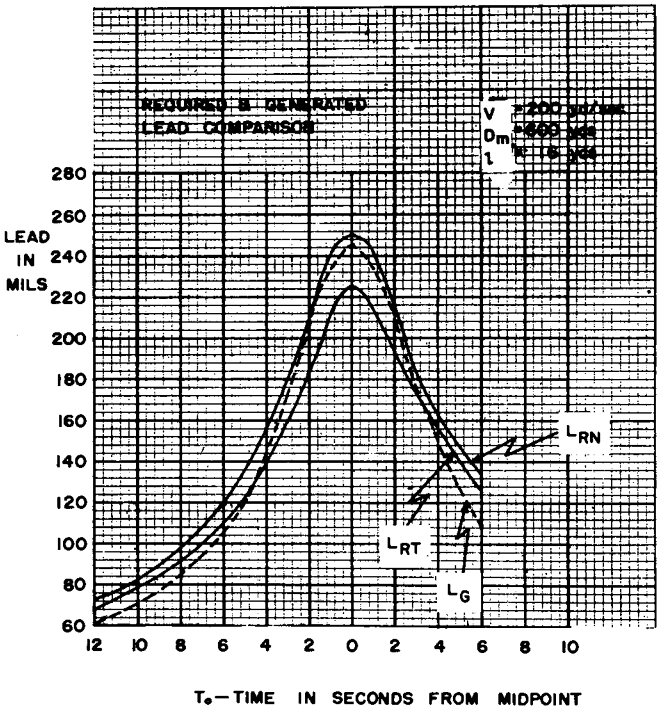


Figure 66. Required and generated leads.

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APPENDIX IV

GLOSSARY OF ANTIAIRCRAFT ARTILLERY AUTOMATIC WEAPONS SYMBOLS AND TERMS

Section I. SYMBOLS

Symbol	*Name*	*Definition*
α	Alpha	Angle of approach.
L	L	Lead angle.
L_G	L sub G	Generated lead angle.
L_R	L sub R	Required lead angle.
D	D	Slant range.
D_m	D sub m	Slant range to midpoint.
D_o	D sub o	Slant range to present (observed) position.
D_p	D sub p	Slant range to future (predicted) position.
E	E	Angular height.
E_m	E sub m	Midpoint angular height.
E_o	E sub o	Present (observed) angular height.
E_p	E sub p	Future (predicted) angular height.
E_s	E sub s	Slant plane angular height.
G	G	Pintle center of the gun.
ϕ	phi	Quadrant elevation.
ϕ_s	phi sub s	Superelevation.
t_p	t sub p	Time of flight.
V	V	Speed of target.
T	T	Target position.
T_m	T sub m	Midpoint.
T_o	T sub o	Present (observed) position.
T_p	T sub p	Future (predicted) position.

Section II. TERMS

Ahead—In tracer observation, a sensing on a tracer, which passes in front of the target.

Angle of approach—The angle formed by T_o, T_p, and G with the apex at T_o.

Angle of site—In surface gunnery, the vertical angle between the gun-target line and the horizontal.

Approaching leg—That portion of the target course line where the target is flying toward midpoint.

Astern—In tracer observation, a sensing of a tracer which passes to the rear to the target.

Center of mass—That point representing the mean portion of matter in a given target.

Climbing course—A target course with increasing altitude.

Cone of sight—In tracer observation, a general cone with the apex at the observer's eye, having a cross section shaped as the contour of the target and extending to infinity.

Crossing course—Any target course which does not pass directly over the gun.

Directly-at-the-gun course—A target course line which passes through the pintle center of the gun.

Diving course—A target course with decreasing altitude.

Downcourse observer—In tracer observation during firing practice, a person stationed a specified distance from a gun or guns opposite the receding leg of a previously determined course for the purpose of obtaining lead sensings.

Eclipse—In tracer observation, a tracer being momentarily blotted out by the target as it passes between the tracer and the observer.

Fly-through—A condition in firing where the lead angle generated by the sighting device is equal to the mathematically correct lead angle required to hit any portion of the target.

Fly-through time interval—The length of time during which a fly-through occurs.

Gunnery chain—A set of four conditions, or steps, which help to meet the two requirements for a hit.

High—In tracer observation, a sensing of a tracer observed to pass above the target.

Horizontal plane—A geometric plane surface established by the point at the pintle center of the gun and all other points at that same elevation disregarding curvature of the earth.

Image spin—The apparent climbing, level flight, and diving of a target while flying a crossing course.

Incoming course—A target flying toward a line erected perpendicular through the pintle center of the gun.

Lead tolerance—Half the angle subtended at the gun by the length of the target.

Level course—A target flying at a constant altitude.

Line—In tracer observation, a tracer which pierces the cone of sight.

Line tolerance—One-half the angle subtended at the gun by the diameter of the target fuselage.

Low—In tracer observation, a sensing on a tracer passing below the target.

On—In tracer observation, a sensing on a tracer correct for line and/or lead.

Outgoing course—A target flying away from a line erected perpendicular through the pintle center of the gun.

Receding leg—The portion of the target course line with the target flying away from midpoint.

Silhouette—In tracer observation, the tracer is superimposed over the target in the background.

Sight reference axis—A line through the optical or geometric center of a sight, perpendicular to the geometric plane formed by the reticles or concentric rings of the sight.

Target course line—A straight line of infinite length formed by the longitudinal axis of a target fuselage.

Target path—The course a target actually takes in flight; not necessarily a straight line.

Tracer control—The art of adjusting fire based on information from tracer observation.

Tracer hump—An optical illusion of curvature of a tracer stream exhibited when firing at moving targets; the point of maximum apparent tracer curvature.

Tracer observation—The technique of visually determining the location of projectile tracers in relation to a target.

Tracer sensing—A decision as to the relative position of a tracer to a target made by observation.

Tracker's line of sight—A line from a tracker's eye through or along a sighting device.

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[AG 472.93 (1 May 56)]

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NG: State AG (6); units—same as Active Army except allowance is one copy to each unit.

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For explanation of abbreviations used, see SR 320–50–1

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