THE GENERAL BOARD

United States Forces, European Theater

Antiaircraft Artillery Section

ANTIAIRCRAFT ARTILLERY TECHNIQUES

Mission: Prepare Report and Recommendations on Antiaircraft Artillery Techniques.

The General Board was established by General Orders 128, Headquarters European Theater of Operations, US Army, dated 17 June 1945, as amended by General Orders 182, dated 7 August 1945 and General Orders 312 dated 20 November 1945, Headquarters United States Forces, European Theater, to prepare a factual analysis of the strategy, tactics, and administration employed by the United States forces in the European Theater.

File: R 353/1

Study Number 40

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THE GENERAL BOARD
UNITED STATES FORCES, EUROPEAN THEATER
APO 408

ANTIAIRCRAFT ARTILLERY TECHNIQUES

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THE GENERAL BOARD
UNITED STATES FORCES, EUROPEAN THEATER

ANTIAIRCRAFT ARTILLERY TECHNIQUES

PART ONE

INTRODUCTION

1. Background, Scope and Purpose. World War II has provided extensive opportunity for the testing of established techniques and the development of new techniques for antiaircraft artillery. The purpose of this study is to examine the techniques used in the recent campaign and to make recommendations for such changes or additions to War Department policy as appear to be indicated. The scope of the study is limited to antiaircraft technical activities in the European Theater commencing with the "Overlord" appreciation (August 1943) and ending with V-E Day.

2. Current War Department Doctrine upon which Changes are Recommended:

a. Antiaircraft artillery operating procedures, including drills.

b. Antiaircraft artillery communications systems.

c. Fire control technique for automatic weapons and guns.

d. Preparation of fire for guns.

THE GENERAL BOARD
UNITED STATES FORCES, EUROPEAN THEATER

ANTIAIRCRAFT ARTILLERY TECHNIQUES

PART TWO

NARRATIVE REPORT OF COMMITTEE STUDY

CHAPTER 1

MOVEMENT AND DEPLOYMENT

SECTION 1

METHODS EMPLOYED IN THE EUROPEAN THEATER

3. Three Different Techniques of Reconnaissance, Selection and Occupation of Position were used by antiaircraft artillery units in the European Theater during World War II.

4. The First Method used was a standard drill for gun, towed automatic weapons, and self-propelled automatic weapons units. The drill was compiled and published by the Theater Antiaircraft Officer.[1] A majority of antiaircraft artillery units assembled in the United Kingdom before Normandy D-Day, 6 June 1944, underwent training in accordance with these movement and deployment procedures. Some units trained intensively at a special movement and deployment school, and others practiced the drill within their own units. A study of the answers to questionnaires submitted by battalion commanders of antiaircraft artillery units employed on the Continent reveals that, in combat, the overwhelming majority used the drill, with or without modification; that most commanders made no comments for changing the drill; and that the majority believed that the movement and deployment drill should be made standard and published in War Department publications.[2] These movement and deployment procedures provided a standard drill which, in normal situations, insured

a. Expeditious dissemination of necessary information relative to movement;

b. Elimination of delay by the accomplishment of accurate route reconnaissance and selection of position, with concurrent march order and loading, and subsequent moving of equipment;

c. Efficient tactical loading, well-directed and expeditious movement, and unretarded occupation of position;

d. The accounting for the loss of any man or vehicle during movement.

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1 P 37 Bibliography Pars 1, 2 and 3
2 P 37 Bibliography Par 4

5. The Second Method used was a combination of the movement and deployment procedures discussed in paragraph 4 above and certain modifications found necessary due to the situation. In general, automatic weapons units attached to divisions found modifications necessary on account of the nature of the missions assigned and the methods used in accomplishing them. In some divisions automatic weapons batteries were almost permanently attached to field artillery battalions, and reconnaissance and movements were made concurrent with the field artillery. Frequently, especially in the armored divisions, missions were assigned to units of less than platoon strength. Such assignments prevented the exact practice of a precise movement and deployment drill. Included also in the units in this category were many semi-mobile units, whose lack of transportation prevented the use of the drill.

6. The Third Method might better be referred to as the "remaining methods". Antiaircraft units which had never been trained in a precise movement and deployment procedure in carrying out the principles of reconnaissance, selection, and occupation of position as published in War Department publications had devised their own procedures on the subject. Variations in methods between these units ranged from great to little, although in most cases the procedures were satisfactory.

SECTION 2

COMPARISON WITH WAR DEPARTMENT DOCTRINE

7. War Department Doctrine[1] lists several methods for making reconnaissance. Reconnaissance for heavy antiaircraft units is covered in Field Manual 44-4, June 1945, which lists the reconnaissance methods for the battalion commander and the battery commander. Both methods outline general procedure and basic principles which, if followed, would insure the advantages listed in paragraph 4 above. However, neither method describes in detail a workable procedure for following basic principles. Field Manual 44-2, December 1944, covers reconnaissance for automatic weapons units. Here again, general procedure and basic principles are outlined, but the detailed technique for the following of the basic principles is lacking.

8. Comparison with Methods Used. The methods of reconnaissance, selection, and occupation of position (movement and deployment), used by antiaircraft artillery units in the European Theater, insured that the general procedure and basic principles outlined in War Department doctrine were followed. However, War Department doctrine provided only a broad general guide upon which the detailed technique employed was founded.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

9. Conclusions:

a. The movement and deployment procedures published by

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1 P 37 Bibliography Pars 5 and 6

Headquarters, European Theater of Operations, were used both with and without modification and produced excellent results.

b. The Antiaircraft Artillery needs published doctrine on the detailed technique of reconnaissance, selection, and occupation of position.

10. Recommendation: It is recommended that published War Department doctrine be expanded to include detailed procedures for movement and deployment of antiaircraft artillery units of like type which can be followed by units in normal situations and which will serve generally as sound guides in any situation.

CHAPTER 2

COMMUNICATIONS

11. War Department Doctrine Changed during the campaign in the European Theater so far as communications for antiaircraft artillery units were concerned. As envisaged in 1943 in publications[1] which were used by units to prepare for the campaign, radio was intended to form the framework of communications for antiaircraft artillery units and a minimum of wire communications equipment was to be included in unit allowances. By 1944, however, the outlook had changed, and wire was declared the most dependable means of communications and was to be used to the fullest extent. Except for self-propelled units and widely separated headquarters, radio was to be considered an auxiliary means of communication.[2] Doctrine concerning responsibility of commanders, coordination, and communications discipline, as applicable to antiaircraft artillery, was to be published in Field Manual 44-1. This manual had not appeared in the list of publications as of 10 July 1945.[3] Doctrine used in the European Theater appears in four late publications.[4] It states that each unit will operate a command net and an intelligence net either by radio or by wire (except self-propelled units) or both, and that alternate means of communications will be provided to be used in case of failure of one of the nets.

12. Techniques Complied with Doctrine so far as available personnel, equipment, and the situation would permit. Separate command and intelligence nets were used by all units when distances were not too great or movement was not in progress. Liaison wire lines were laid between antiaircraft artillery units and units of other branches and, when transmission was good and traffic permitted, it was sometimes possible for any unit to communicate by wire with almost any other unit in the entire European Theater. Generally speaking, however, communications were slow and frequently ineffective in spite of the effort expended.

13. Deviations from Doctrine consisted mainly of improvisations required to compensate for inadequacy of equipment and personnel. This inadequacy is mentioned in a General Board study on organization and equipment but is mentioned herein on account of its bearing on technique.

a. Perusal of tables of organization and equipment[5] reveals that a realistic interpretation of doctrine was not employed in providing for 'round-the-clock' operation. Units were compelled to shift men among sections and batteries to permit operation not only of equipment allowed, but equipment drawn from the Signal Corps to supplement what had originally been furnished.

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1. Par 134a, FM 4-100, 28 June 1943.
2. Par 37, FM 44-2, December 1944 and reiterated in Par 29, FM 44-4 June 1945.
3. FM 21-6, 10 July 1945.
4. FM 44-8, 10 August 1944; FM 44-2, December 1944; FM 44-6, March 1945; FM 44-4, June 1945.
5. P 37 Bibliography Par 7. For example, it is to be noted that a brigade is allowed eight operators to man three radios; a group, seven for three radios; and a battalion, four for three radios. None of these allowances permit 'round-the-clock' operation and no justifiable reason can be found for the variation in numbers.

b. Radios provided in tables of equipment lacked uniformity as to type, lacked adequate remote-control facilities, and were generally inadequate in number, frequency, and range. Additional radios of sufficient power were drawn from the Signal Corps to supplement those issued.

c. Wire communications technique differed from that contemplated in field manuals. In order to expedite the laying and maintenance of wire, lines were frequently laid to a unit by a lower echelon,[1] and nets of units other than antiaircraft artillery were used. Switching centers of divisions, corps, and other units were frequently used by antiaircraft artillery battalions and higher echelons. The techniques employed to establish primary and alternate nets, as well as liaison lines to units of other branches, are so numerous as to preclude profitable discussion in this study. The utilization of four to five times the allowance of wire frequently occurred, and was necessary. The task of laying and maintaining was far beyond the capability of communications personnel allowed.

14. Conclusions and Recommendations.

a. Conclusions:

(1) Tables of organization and equipment did not permit a universally efficient system of continuous communications, as envisaged by War Department doctrine.

(2) Communications need complete revision.

b. Recommendations. It is recommended that:

(1) Communications be standardized.

(2) Adequate equipment be designed and provided.

(3) Adequate personnel be provided.

(4) Techniques of communication be developed to fit future operations and be published in field manuals.

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1. A popular technique was as follows: Wire was initially laid clockwise around a defense--Battalion to Btry A, A to B, B to C, C to D, and D to battalion. Internal wire in headquarters and batteries was laid by personnel other than linemen.

CHAPTER 3

FIRE DIRECTION

SECTION 1

WAR DEPARTMENT DOCTRINE ON FIRE DIRECTION

15. Definition of Fire Direction. As stated in Field Manual 4-100, 28 June 1943, and reiterated in all pertinent field manuals issued since that date,[1] fire direction is defined as: "The exercise of the tactical command over one or more fire units in the selection of targets, in the appropriately timed concentration or distribution of fire thereon, and in the restriction or release of fire."

16. Responsibility of Commanders. According to the doctrine contained in Field Manual 4-100, which was the basic doctrine under which antiaircraft artillery units were trained, the fire unit commander was responsible for fire direction under restrictions and rules for target priorities imposed by standing operating procedures;

a. When time did not permit establishment of a suitable command net,

b. When fire units were so widely separated as to preclude practical direction by a higher echelon, and

c. Whenever it appeared to be the best method.

Fire direction was to be exercised by echelons above the fire unit in stabilized and highly organized defenses (except for automatic weapons battalions). No substantial change in doctrine on responsibility occurred after 28 June 1943, but antiaircraft artillery operations rooms were universally adopted for warning purposes and as vehicles for the exercise of fire direction by echelons above the fire unit.[2] Thus, when the campaign on the Continent began there were two methods of exercising fire direction in use by echelons above the fire unit. One was indirect, by means of rules for engagement according to which the fire unit commander could operate even when communications failed; one was direct, by means of which either his targets could be assigned, or "RELEASE" and "HOLD FIRE" orders could be issued from an operations room.

17. Fire Restriction. Doctrine of 1943 states: "Restrictions will be imposed on the minimum number of antiaircraft artillery units consistent with the accomplishment of the desired aim." Emphasis was placed on the necessity for freedom of fire, but no detailed rules for restriction were given. By 1944, however, the need for such rules was realized, but the responsibility for the promulgation thereof was placed on theater commanders.[3]

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1. FM 44-2, December 1944; FM 44-4, June 1945; FM 44-8, 10 August 1944.
2. See FM 44-8, 10 August 1944.
3. See, for example, par 23d, FM 44-4, June 1945.

SECTION 2

FIRE DIRECTION IN THE EUROPEAN THEATER

18. The General Plan for Fire Direction in the European Theater was formulated by the Supreme Commander in carrying out his responsibility referred to in paragraph 17 above. The plan, in general, was as follows:

a. Selection of targets and the timing and distribution of fire thereon was to be accomplished by fire unit commanders and local antiaircraft defense commanders.

b. To safeguard friendly aircraft, flying over certain defended areas was to be restricted and rules for engagement of aircraft corresponding to the degree of restriction were prescribed.

c. Antiaircraft artillery operations rooms were to be the vehicles for fire direction by local antiaircraft defense commanders and commanders of higher echelons.

19. Selection of Targets and the delivery of fire thereon were actually accomplished by fire unit commanders almost exclusively. In the exercise of this function they were guided by the elaborate rules for engagement issued by the Supreme Commanders and such "HOLD FIRE" and "RELEASE FIRE" orders as they received from operations rooms. Rarely was a direct order to fire on a particular target issued from an operations room and seldom was a target position furnished a fire unit in any manner other than by general warning of its presence near the defended area.[1]

20. Rules for Engagement of aircraft by antiaircraft artillery were issued initially by the Supreme Commander in the European Theater, in Operations Memorandum Number 7.[2] Among other things, the memorandum contains the following:

a. Definitions of the terms "Recognized", Identified", "Friendly Aircraft", "Hostile Aircraft", "Hostile Acts", "Restricted Areas", "Unrestricted Areas", "An Attack Is In Progress", and "An Attack Has Closed".

b. General rules for engagement in unrestricted areas and in restricted areas for both fire at seen targets and unseen targets.

c. Classes of restricted areas: "Inner Artillery Zones", "Gun Defended Areas", "Beaches", and "Airfields".

d. Specific rules for engagement of both seen and unseen targets in each type of restricted area.

21. Application of the Initial Rules for Engagement became impracticable because of their complexity. Both the Air Force and the Antiaircraft Artillery, neither of which had been trained in their use prior to arrival in the European Theater, were confused. Consequently, shortly after the invasion only two types of areas were extensively used--the

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1. Exception to this general situation occurred in the so-called "Diver Belt" where pilotless aircraft attacked from relatively fixed directions and between certain altitudes.
2. F 37 Bibliography Par 8.

unrestricted area and the inner artillery zone.

22. Rules for Engagement in Unrestricted Areas. All areas not specifically designated as restricted areas were unrestricted to flying. In unrestricted areas antiaircraft artillery could and would fire at all targets actually recognized as hostile or which committed a hostile act. In addition, fire at unseen targets was permitted if consent was obtained from an air force area controller, or, in the absence of communications with a controller, when an attack was in progress and the local antiaircraft commander considered fire necessary for the protection of the area defended.

23. Inner Artillery Zones. With certain modifications the type of zone restricted to flying known as the inner artillery zone (IAZ) was the most widely used. Such a zone was usually an imaginary cylinder of radius 12,000 yards and ceiling of 10,000 feet above sea level with center at the center of the defended area. Since the restrictions on flying and the rules for engagement of targets applied only during the hours of darkness, the inner artillery zone existed only at night and, therefore, the area it covered was unrestricted by day. While the inner artillery zone was in effect the following rules applied:[1]

a. "Friendly aircraft will be prohibited from flying through an IAZ, and those entering an IAZ are likely to be engaged."

b. "'HOLD FIRE' will not be given during darkness, but fire may be withheld by the Antiaircraft Defense Commander if the area controller so requests. Such requests will be made only to avoid endangering friendly aircraft, and will be complied with whenever possible without prejudice to engagements in progress."

c. "Antiaircraft artillery will fire on all seen targets not identified or recognized as friendly in an IAZ . . . unless 'HOLD FIRE' has been ordered. If 'HOLD FIRE' has been ordered, aircraft must be recognized as hostile or commit a hostile act before fire is opened."

d. "(By night) Fire will be opened by Antiaircraft artillery, except light AA, on all unseen aircraft not identified as friendly. Light AA will not engage unseen aircraft except for prearranged barrage fire directed by the AA Operations Room."

e. "Normally antiaircraft artillery not in communication with an AA Operations Room will not engage unseen aircraft. To provide for a contingency, such as a breakdown in communications, when an attack is in progress . . . any unseen aircraft not identified as friendly may be engaged until the attack ceases or communications are restored."

24. Adequacy of Inner Artillery Zones. Employment of inner artillery zones was a mixture of successes and failures--partial successes owing to the freedom afforded the antiaircraft artillery, and failures owing to the lack of positive means of identification and the adverse effect that the zones had on bomber operations.

a. Identification. Any identification, friend or foe, (IFF) radar response from an aircraft was accepted by the antiaircraft artillery as friendly identification while the absence of such a response

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1. P37 Bibliography Par 8.

merely left the aircraft unidentified.

b. Freedom of Action. It is noteworthy that the inner artillery zone rules for engagement applied if the fire unit was in communication with an antiaircraft operations room, and communication with an area controller (Air Force) was not essential. As every antiaircraft defense invariably established an antiaircraft operations room of some type, the inner artillery zone rules applied even though there was no communication with air force controllers. On the one hand, this freedom of action was of immense benefit to antiaircraft units in accomplishing their mission during the periods of rapid advance by our armies in August and September 1944.[1] On the other hand, on account of lack of positive identification, this freedom was a source of great anxiety to isolated defense commanders when a few craft of a huge formation responded to radar challenge but most of them did not. It also resulted in fire being placed on some friendly aircraft.

c. Effect on Bomber Operations.

(1) Owing to the successful antiaircraft defenses of the lines of communications which resulted from the employment of inner artillery zones, the armies established these restricted areas at every river crossing or bottleneck. By 7 September 1944 an almost continuous chain of inner artillery zones existed between Antwerp and Nancy (VU8612).[1]

(2) Royal Air Force Bomber Command maintained that the situation was intolerable, since to fly around the restricted areas would unduly lengthen their routes; owing to weather conditions, planes could not always fly over the zone ceiling; to channel all flights through the few gaps in the chain would give a good advantage to the German night-fighters.

(3) The problem of protecting friendly bombers was further complicated by the fact that the Royal Air Force Bomber Command did not employ radar identification, friend or foe, since it was feared that German night-fighters "homed" on the signal. Even had it been employed, mass flights would saturate receivers so that individual planes could not be identified. A reliable identification system would have solved the entire problem.

(4) The initial solution of the problem was to limit the number of inner artillery zones so that friendly bombers would have reasonably wide unrestricted routes. This compromise did not solve the problem, as neither the armies nor the Bomber Command felt they had sufficient freedom of action.[2]

25. Modification of Rules for Inner Artillery Zones. On account of the adverse effect on bomber operations, it was necessary to adopt special measures to protect heavy bombers operating at night. The system adopted was prescribed in Air Defense Instruction Number Five.[3] The essential changes to previous instructions were as follows:

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1. P 37 Bibliography Par 9.
2. P 37 Bibliograohy Par 10.
3. P 37 Bibliography Par 11.

a. Inner artillery zone rules did not apply if the zone was out of communication with a fighter control center (area controller).

b. Controllers were to rely on movement notifications (received at least four hours before the expected arrival of heavy bombers over inner artillery zones) for identification.

c. Controllers were to notify restricted areas affected by the movement message of the time limit the restriction would be effective, allowing normally not more than 30 minutes for the outgoing flight and 45 minutes for the return flight. The "restriction" was not defined; however, in practice it amounted to a "HOLD FIRE" order to the units in the inner artillery zones between specified time limits. This system was never satisfactory from the standpoint of the antiaircraft artillery defense. Notifications of movements from England were frequently not received and, when received, they were often expressed in such general terms that the geographical limits and time limits of the flights could not be accurately determined. "HOLD FIRE" periods were of unnecessarily long duration. Even when "HOLD FIRE" was not in effect, the fire unit commander often had a strong suspicion that the planes overhead were friendly.[1]

26. Other Methods of Fire Direction. With the application of Air Defense Instruction Number Five, the chief advantages of the inner artillery zone were lost. Other systems were devised between the armies and the tactical air commands whereby freedom of action for antiaircraft artillery was obtained for limited periods even though the areas were not restricted in the sense defined in Operations Memorandum Number Seven. Whenever the controller at the fighter control center was sure that for a certain period of time an area would be free of friendly aircraft, antiaircraft artillery units would be released to fire on targets not identified as friendly. The details of this method as applied in Third United States Army are contained in Operation "Blankcheck".[2] This system had an advantage in that the areas could be agreed upon between the Army and the Tactical Air Command without clearance through higher headquarters. For the system to function, however, elaborate communications were required, and the controller had to have complete information on friendly flights. Some controllers were reluctant to assume the responsibility of releasing fire for several reasons, among which was lack of confidence in movements liaison information and, therefore, this system also was unsatisfactory.

27. Fire Direction by Group and Battalion Antiaircraft Operations Rooms. Fire direction, in the sense of selection of targets and the concentrating or distributing of fire, was of limited scope above the fire unit level. In general, it consisted simply of assigning primary sectors to each gun battery and coordinating radar search.[3] Group and battalion antiaircraft operations rooms, in some cases, would relay "HOLD FIRE" and "RELEASE FIRE" instructions from the fighter control center to lower echelons.

28. Fire Direction at the Fire Unit. The lack of enemy mass-formation attacks simplified the problem of fire direction in the European Theater. In gun battalions, fire units were assigned primary and contingent sectors, the contingent sectors comprising all areas within range of the guns not included in primary sectors. If no target was present in the primary sector, and "HOLD FIRE" was not in effect, guns were free to

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1. P 37 Bibliography Par 12.
2. P 37 Bibliography Par 13.
3. P 37 Bibliography Par 14.

engage any target anywhere within the restricted area. On occasions where more than one target was in the primary sector, the closest approaching target was selected. Automatic weapons fire direction at the fire unit was even simpler. Because of the extremely short time that targets were in the field of fire, little opportunity for selection of targets existed. If an aircraft was in range and a proper target within the rules for engagement, the fire unit commander opened fire on it. On the few occasions where multiple targets were in the air, the closest approaching target was engaged.

SECTION 3

COMPARISON WITH WAR DEPARTMENT DOCTRINE

29. Fire Direction by Establishing Rules for Engagement was developed to a high degree in the European Theater. It is to be noted, however, that no standard rules for engagement are given in the War Department publications on the subject of fire direction. While no universal system can be prescribed, the subject should be covered in more detail. Units arriving in the European Theater were usually unfamiliar with restricted areas and any kind of rules for engagement other than rules on target priorities.

30. Fire Direction by Antiaircraft Operations Rooms, as indicated in Section 2, was limited to giving release and hold fire orders, assigning primary sectors, and coordinating radar search. Selection of targets and concentration of fire on most dangerous targets were not attempted by the operations rooms for the following reasons:

a. There was lack of confidence in the air warning service. The antiaircraft commanders were more confident in the ability of the fire units to pick up targets than they were in the information available at the operations room.

b. Placing the fire control radar SCR-584 on a plotted course was difficult. Owing to the narrow beam, the SCR-584 operator had considerable difficulty picking up specific targets. Commanders preferred to rely upon some radar in a defense picking up targets in normal search rather than to assign a target to a specific fire unit which might not be able to get on the designated target.

c. Mass raids did not occur. When a limited amount of antiaircraft artillery must defend an area subjected to saturation raids, and an efficient long-range warning system is present, it is agreed that centralized fire direction is more economical than direction by the fire unit commander. As saturation raids did not occur, the necessity for such control did not exist.

31. Fire Direction by Fire Unit Commanders. Considering the types of targets presented and the limitations of equipment, fire direction by the fire unit commanders, as described in Section 2, conformed to War Department doctrine.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

32. Conclusions:

a. The current War Department doctrine on antiaircraft artillery fire direction is inadequate.

b. Rules for engaging aircraft in the European Theater were too voluminous and complex.

c. Improvement in equipment, incorporating adequate search features and insuring positive identification of aircraft by fire units, would have permitted simplification of the rules for engagement and removed many restrictions to flying.

33. Recommendations: It is recommended that:

a. A system of positive identification, friend or foe, be developed and used by antiaircraft artillery units,

b. An adequate search instrument be developed to enable fire units to detect targets and to direct fire control instruments to any specified target, and

c. Rules for engagement of aircraft be standardized for all theaters and published in War Department field manuals.

CHAPTER 4

AUTOMATIC WEAPONS GUNNERY

SECTION 1

LIMITATIONS OF FIRE CONTROL EQUIPMENT

34. Published War Department Doctrine on the principles of automatic weapons gunnery, as applied in the European Theater, proved to be sound. However, because of the limitations of the automatic weapons fire control equipment, the application of the published principles was insufficient to produce entirely satisfactory results. Destruction of aircraft resulted largely from volume of fire delivered, and not from the efficiency of fire control equipment.

35. Automatic Weapons Fire Control Equipment was unsatisfactory for several reasons. It was not suitable for firing during darkness. Each of the many types of fire control used required that the operator estimate at least one element of the firing data. The accuracy of these estimations varied with individual operators, based upon the degree of their training on the equipment; and in the heat and excitement of combat engagement, estimations became universally poor. The usual high speed, hedge-hopping, hit-and-run tactics of the German Air Force, coupled with the very high speed and change-of-pace tactics of the jet-propelled aircraft in the final stages of the campaign, accentuated the discrepancies in data estimation, and revealed further inadequacies in both our on-carriage and off-carriage fire control systems.

SECTION 2

ON-CARRIAGE SIGHTS

36. The M2 Sighting System (Forward Area) was unsatisfactory and inadequate for the following reasons:[1]

a. Gunners estimated speed of targets.

b. Gunners adjusted fire by tracer observation.

c. It was designed for speeds lower than those usually encountered. For speeds above 300 miles per hour, gunners had to visualize or estimate where appropriate speed-lines should have been had they been placed on the sight--obviously a very difficult thing to do.

d. Although this sight was instrumental in destroying a considerable number of planes, it is believed that hits were obtained not through the application of precise gunnery, but because the gunner set a constant speed and let the target fly through the cone of fire, which was an effective method at times, but exceedingly wasteful of ammunition.

37. The Speed-Ring Sight was unsatisfactory and inadequate.[1] Although claimed to be more accurate than the M3, it also required estimated data. This sight was used primarily on the caliber .50 water cooled machine guns. No caliber .50 heavy barrel machine guns and few 40 millimeter guns were equipped with it.

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1. P 37 Bibliography Par 12.

38. The Navy Mark IX, Speed-Ring Sight, was unsatisfactory[1]. It was designed for incoming courses--in which use it is superior to other sights--but it is too flimsy in construction and difficult to orient. It, too, required estimated data.

39. The Stiffkey-Stick was unsatisfactory because it was not designed for fast moving targets, required estimated data, and, by the nature of its construction, unduly exposed the gunner to attacking planes. It was, however, the best of the automatic weapons fire control--rugged (opinions varied)[1], simple in construction, requiring little maintenance, and quite accurate against moderate speed targets. It had one decided advantage over other on-carriage sights in that hits were possible without tracer control. This sight was also instrumental in obtaining hits because the gunner reverted to the aforementioned "Fly-through" principle. Nearly all automatic weapons battalions of the First and Third United States Armies were equipped with this sight.

40. The Computing Sight M7 (Weissight), like all other on-carriage sights, was fundamentally unsatisfactory in that it required human estimation of a variable in its operation. It was designed to use only horizontal speeds, which were estimated. If the target dived or climbed, the actual speed was estimated and then mentally converted to horizontal speed. Theoretically, hits could be obtained within a speed tolerance of 25 miles per hour. But the ability of the average gunner to estimate speeds within that limit of targets exceeding 200 miles per hour is questionable. There also were objectionable features in construction reported[1]. It was too flimsy to withstand hard service; the telescopes had too limited a field of view, "blacked--out" easily from vibration during firing, and fogged up in cold or damp weather; the computing box collected excessive moisture, thereby causing the gears within to rust or freeze up; there was excessive backlash in the linkage, and cables stretched; and, the sight got out of level easily. The M7 sight was never used to a great extent in the First United States Army but had a wide distribution in other commands. Of the using battalions, approximately half reported it as satisfactory[1].

41. The Computing Sight M14 and the M5 and M6 Sighting Systems have been insufficiently reported upon to form a conclusion as to their merits. However, they require speed estimation by the operating personnel, and for that reason alone are unsatisfactory.

SECTION 3

OFF-CARRIAGE FIRE CONTROL

42. The M5 and M5A1 Directors were unsatisfactory for the following reasons:

a. They required range estimation by the operating personnel.

b. Their weight made them difficult to handle and transport.

c. They required highly-trained personnel to operate[1].

d. The operating personnel could not pick up or track close-in, high-speed, low-flying or fleeting targets[2].

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1. P 37 Bibliography Par 12.
2. P 37 Bibliography Par 15.

e. They required continuous and careful orientation with respect to guns.

For the reasons stated above, these directors, although issued to a considerable number of battalions, were little used. They were either withdrawn, as was done in the First United States Army, or retained in unit storage and replaced by some type of on-carriage sight.

43. The M542 Director was used by only a few battalions and then on a very limited scale. No reports on its operation are available and therefore it will not be included in this report.

44. The T26 Radar Director for automatic weapons made its appearance only in an experimental form. The 71st Antiaircraft Artillery Group conducted experiments with it employing pilotless aircraft as targets but the use of inexperienced and untrained operating personnel prevented conclusions from being drawn as to its efficiency[1]. Fast and low-flying aircraft with great maneuverability have decisively demonstrated the need for some type of fire control equipment eliminating the human estimation of speed, range, or direction of flight.

SECTION 4

BARRAGE FIRE

45. Automatic Weapons Barrage Fire has been a very controversial subject among antiaircraft artillery officers in the European Theater. Responses to Antiaircraft Artillery Questionnaire, Headquarters European Theater of Operations, 11 June 1945, indicate two definitely opposed opinions. One group of officers maintains that barrages were ineffective and wasteful of ammunition; the other group maintains that barrages accounted for several enemy planes and that they were, if controlled, instrumental in preventing the enemy from making determined bomb runs[2]. It is believed that radar fire control equipment will eliminate any necessity for barrage fire.

SECTION 5

SECONDARY ROLE

46. Ground Firing was conducted by many automatic weapons battalions during the European Campaign using both direct and indirect methods of fire control[3]. The 40 millimeter gun was not equipped with indirect fire control equipment; therefore, such equipment when needed had to be improvised.

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

47. Conclusions:

a. Present fire control equipment for automatic weapons is unsatisfactory.

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1. P 37 Bibliography Par 16.
2. P 37 Bibliography Par 12.
3. P 37 Bibliography Par 17.

b. Barrage fire by automatic weapons is justified when controlled, but the necessity for it will disappear when suitable fire control methods are adopted.

48. Recommendations. It is recommended that:

a. Radar fire control equipment for automatic weapons larger than 20 millimeter be developed with the following characteristics: mounted on the same carriage with the weapon; operated by one man; small in size and light in weight; capable of detecting aerial targets at 30,000 yards slant range and from zero to 85 degrees in elevation; capable of accurate automatic tracking, computation of firing data and gun laying for firing at unseen targets on any type course at speeds up to 1,000 miles per hour.

b. An on-carriage computing sight, operated by one man, capable of tracking aerial targets at speeds up to 1,000 miles per hour, and not requiring any element of firing data to be estimated, be developed for automatic weapons smaller than 37 millimeter guns.

c. All automatic weapons be equipped with suitable sights for terrestrial fire, direct and indirect.

CHAPTER 5

GUN GUNNERY

SECTION 1

DEVIATIONS FROM WAR DEPARTMENT DOCTRINE

49. The Basic Principles of Doctrine on gunnery from which deviations were reported by antiaircraft artillery gun battalions[1] employed in the European Theater are the following:

a. Ammunition of a given lot number

(1) is such that, under standard conditions, muzzle velocities are produced which vary between narrow limits, and

(2) is issued in quantities which will assure a sufficient number of rounds for engaging targets after the lot has been tested by trial fire.

b. Measurement of the time of flight of a projectile by a stop-watch is sufficiently accurate for analysis of fire.

c. A uniform dead time of maneuver[2] can be achieved by drill.

50. Other Principles of gunnery technique less basic in character which require modification are the following:

a. Satisfactory analysis of fire can be achieved by the firing of trial fire.

b. Time fire registration for ground targets can be accomplished by present field artillery methods.

c. When the fire control instruments of a battery fail, it is advisable to fire by present position data received from another battery.

d. Barrage fire under certain circumstances is desirable.

51. Deviations from Doctrine.

a. Ammunition as issued in the European Theater during the greater part of World War II was such that useful analysis of fire was impossible. Not only did the number of powder lots in a given organization become so great that few lots contained sufficient rounds for engaging a target after trial fire rounds had been fired[3], but frequently

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1. P 39 Bibliography Par 15.
2. The length of time it takes to fire a shell after its fuze has been set.
3. Battalions have reported as many as 65 lots for 1,800 rounds. In an effort to even up the lots, the 98th AAA Brigade supervised the exchange of all small lots in the gun battalions of the Third U.S. Army in December 1944.

wide variations in muzzle velocity occurred among rounds of the same lot.[1]

b. Under variable field conditions, timing by a stop-watch within an error of less than a tenth of a second is unlikely, and errors of this order may produce great variations in slant range. The usual procedure was to determine time of flight to the best of one's ability, and then attribute any remaining deviation of bursts to errors in laying, muzzle velocity, and inaccuracies in meteorological data.

c. In the defense of Antwerp against pilotless aircraft, a salvo method of fire was adopted which, among other things, produced a very accurate dead time by having the fuze cut on one signal and the round fired on the next, four seconds later. The results were highly gratifying for that particular operation..

d. Many units fired only a single trial shot problem to determine ballistic corrections. Much more satisfactory results were obtained when units based their corrections on the average result of firing at two or more points.

e. Present field artillery methods for time fire registration were designed primarily for howitzers. They are not practical for flat-trajectory weapons except under favorable circumstances. Field artillery doctrine was the only War Department guide by which antiaircraft artillery gun units fired ground missions for a large portion of the campaign. The old angle of site method was resuscitated for use with the 90 millimeter gun.

f. Much valuable time has been wasted on remote-data control systems which could otherwise have been used for other purposes. No record has been found in the European Theater of the firing of one battery using present position data received from another battery. When fire control instruments failed in a battery it went out of action.

g. There appears to be no record of barrage fire by 90 millimeter guns in the European Theater but there is an extensive record of recommendations that it not be employed.

SECTION 2

PREPARATION OF FIRE

52. Preparation of Antiaircraft Fire, except for minor details, followed procedures outlined in existing doctrine.

a. Orientation was often done by backsighting on the tracker and checked by sighting on a celestial body or distant terrestrial point; or by removing all predictions from the instruments, tracking an airplane and viewing it through the gun tubes. In many positions, where the radar site would not permit backsighting by the radar telescope, an observing telescope or an aiming circle was set up at a distance and all guns and instruments oriented with respect to it. This latter method has the advantage of avoiding errors due to parallax between the radar telescope and the electrical axis of the paraboloid, which parallax becomes

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1. Battery "D", 119th AAA Gun Battalion, returned one lot of 100 rounds which produced range variations up to 285 yards. Other organizations experienced comparable variations.

pronounced at short distances.

b. Meteorological messages were mostly of the modern Rawin-radiosonde type but did not contain ballistic temperatures by zones. Quite frequently gun battalions used field artillery messages for obtaining densities and temperatures, and by frequent comparisons between the two types of messages could use the latter for ballistic winds during intervals between Rawin messages[1]. Inasmuch as gun units were not provided with thermometers, they used a meteorological message four hours old for powder temperature.

c. As indicated in paragraphs 51b and 51d above, trial fire was conducted according to doctrine, employing, for the most part, unilateral observation from a radar. The trial fire was valuable so far as check-fire was concerned because most targets fired upon appeared in a zone which included the trial shot point. The adoption of an electronic chronograph and timing device as standard antiaircraft artillery equipment will insure that current muzzle velocity is used in preparation of fire.

53. Preparation of Ground Fire followed doctrine as laid down for the Field Artillery, except in the case of time fire registration. Because of the relatively small angle of fall of the 90 millimeter shell, cutting its fuze back from the time of flight to an impact burst by increments of four tenths of a fuze number not only produced an air burst but also seriously shortened the range[2]. To circumvent this obstacle the fuze was cut back two tenths of a second at a time until an air burst was obtained, a mean was determined and then the bursts lifted in quadrant elevation to produce the desired height of burst, and again cut back along the line of fall to spray the target effectively. The fuze obtained after the final cut-back was the adjusted time. Due to difficulty of observing the small burst and to the difference between the propelling charges for the impact and time shells, the process was tedious and provoking.

SECTION 3

ADJUSTMENT OF FIRE

54. Adjustment of Antiaircraft Fire was not practiced. A study was made of the feasibility of making adjustments of fire against pilotless aircraft by unilateral radar observation, but nothing beyond an indication of its possibility was developed[3].

55. Adjustment of Ground Fire, when used, followed doctrine as prescribed for the Field Artillery. Because of its all-around traverse, and consequent wide dispersion of check points over a very great target area, a 90 millimeter unit could transfer fire more accurately without adjustment than field artillery units, which had to shift trails to cover the same area.

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1. Rawin and radiosonde are discussed in TM 20-240.
2. For example, at 15,000 yards range the angle of fall is about 38 degrees and the terminal velocity 945 feet per second. A cut-back of 0.4 seconds shortens the range by about 110 yards and all effect on a target would be lost on the final adjustment.
3. P 38 Bibliography Par 19.

SECTION 4

FIRE FOR EFFECT

56. Fire for Effect at Aerial Targets generally followed established doctrine until the proximity fuze[1] was introduced. Since many of the targets engaged were single planes on reconnaissance, a special technique was introduced for such craft. Fire was opened with the proximity fuze to obtain surprise and followed by the time fuze to insure harassment when the target maneuvered. Some units planned to fire "Time on Target"[2] concentrations on such a target to obtain maximum destructive effect but, due to the paucity of targets, the plan was not perfected. Practically all fire was controlled by radar data using either "unseen" or "seen-unseen" cable systems[3]. It is believed by the majority of unit commanders that completely unseen methods are practicable but that retention of the seen-unseen method is desirable.

57. Fire for Effect at Ground Targets generally followed established doctrine. Innovations introduced, so far as antiaircraft artillery units were concerned, included mixing time and impact fuzes, using delay fuzes to obtain effective air bursts in heavy woods, and using continuous rapid time-fire to pin an enemy to the ground while heavier artillery engaged him. All units committed to the ground role used graphic firing tables at some time or other, and usually computed their own data.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

58. Conclusions:

a. Ammunition issued in the European Theater was of so many different lots of varying characteristics that it produced great dispersion.

b. Using corrections based on the results of only one trial shot problem is unsatisfactory.

c. Time fire registration, according to Field Manual 6-40, 1 June 1945, is not applicable to flat-trajectory, high-velocity weapons.

d. Standardization of dead time solely by drill is open to question.

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1. A variable time fuze, popularly called the Pozit, which causes a burst when the shell arrives in the close vicinity of the target without the use of a time element.
2. Fire by two or more batteries delivered in such a manner that all bursts occur simultaneously.
3. "Seen" fire is fire delivered by visual observation of the target with range supplied by an outside source such as a radar. "Unseen" fire is fire delivered entirely by radar data. "Seen-unseen" fire is fire delivered by alternating the two preceding types by means of a switching procedure.

e. Firing one battery by present position data received from another battery was not practiced.

f. Barrage fire by 90 millimeter guns is not desirable.

59. Recommendations: It is recommended that:

a. Ammunition of standard characteristics[1] be furnished,

b. Doctrine include the trial shot problem as consisting of firing on two or more points,

c. Field chronographs and timing devices be adopted as organizational antiaircraft artillery equipment,

d. Technique be developed for time registration of flat-trajectory, high-velocity guns,

e. Plans for firing one battery by present position data received from another battery be abandoned, and

f. Under normal conditions barrage fire not be used by gun units.

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1. 20 foot-seconds variation in muzzle velocity is considered to be the maximum acceptable tolerance.

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CHAPTER 6

DRILL PROCEDURES

SECTION 1

AUTOMATIC WEAPONS AND SELF-PROPELLED UNITS

60. Procedures Used in the European Theater. Drill procedures used by units in the European Theater varied from the drills prescribed in field manuals for the following reasons:

a. Field manuals prescribe drills based on complete crews. Owing to the necessity of manning guns 24 hours a day and the lack of early warning in the forward areas, complete crews were rarely available during engagements.

b. Many units were equipped with the Stiffkey-Stick on-carriage sight. As this sight is of British origin, an official United States drill for its employment is not available.

c. Field Manual 4-160 describes procedures for use with the director and forward-area sight only. Directors were rarely used, and all units had some type of on-carriage sight other than the forward-area sight.

61. Drill References.

a. In general, War Department field manuals were used as guides by all units. In answering a questionnaire[1] on drill procedures, only five of 107 battalion commanders stated that their units had used texts other than the field manuals.

b. On 19 July 1944, the Antiaircraft Officer, European Theater of Operations, published a modified drill for the 40 millimeter fire unit, prescribing procedures for units equipped with the Stiffkey-Stick and M7 Computing sight.[2] This publication was not distributed to units assigned to the field forces or to the IX Air Defense Command. The battalion commanders' replies to questionnaires indicate that this procedure was not generally used.

c. First United States Army also issued a modification of Field Manual 4-160 to adapt the drill to the Stiffkey-Stick and the M-16B half-track. Only one battalion commander stated that this publication was used by his unit.[1]

d. The subject of movement and deployment procedures, which may be considered as a drill, is covered in Chapter 2 of this study.

62. Comments of Battalion Commanders on Drill Procedures. The following comments are based on replies of 107 battalion commanders to a questionnaire[1] on drill procedures:

a. Forty-five stated that prescribed drill procedures are satisfactory, and recommended no changes. Eight made no comment.

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1. P 37 Bibliography Par 12.
2. P 38 Bibliography Par 20.

b. Twenty-nine stated that prescribed drills were not completely satisfactory in that no provision is made for a drill for the minimum alert crew.

c. Nine stated that drills were too detailed to follow under combat conditions.

d. Five stated current drills have too many verbal commands, which often are not heard under combat conditions.

e. Four stated that present drills are unsatisfactory in that they do not consider emplacing the gun in a revetment, which was almost invariably necessary in combat.

f. Not more than two battalion commanders agreed on any other comment.

63. Conclusions and Recommendations.

a. Conclusions:

(1) Prescribed drills were used only as guides in the European Theater, but as guides they were generally satisfactory.

(2) A standard drill for minimum manning crews should be prepared.

b. Recommendations: It is recommended that:

(1) Current drill procedures be revised to incorporate procedures for all standard fire control equipment,

(2) A minimum manning crew drill be prepared, and

(3) The War Department issue field manuals covering all pertinent drills.

SECTION 2

NINETY MILLIMETER GUN UNITS

64. Procedures Used in the European Theater.

a. Gun units were able to follow prescribed drill procedures more closely than automatic weapons units because no major non-standard item of equipment was used and because all equipment contemplated in the field manuals was employed. However, drills were modified to permit firing with minimum manning crews, and the employment of proximity-fuzed ammunition required some alteration of the drill.

b. One notable modification of the standard drill was made in the defense of Antwerp against pilotless aircraft where salvo fire was used. This system was discussed in paragraph 51c, above. Before the worth of the system could be definitely evaluated for general use, proximity-fuzed ammunition was employed, thus eliminating the need for salvo fire.

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65. Drill References. Four of 46 battalion commanders stated in answering a questionnaire[1] that they used texts other than War Department publications. Two of these units came overseas before drills were published, and improvised their own drills. The other two referred to operations instructions which prescribed a standard method of engagement.

66. Lack of Coordinated Drill Procedures.

a. Field manuals prescribe a service of the piece for all the guns and for each individual item of fire control equipment. There is no prescribed drill for the battery as a whole where standardized commands by the officer conducting fire are enunciated. While the emplacement procedures for the individual items of equipment is complete, there is no War Department publication prescribing a procedure for coordinating the emplacement of the individual items.

b. As a result of the lack of coordinated drill procedures there was a lack of uniformity among battalions. An officer not familiar with the customary methods of a battery could not conduct fire until he had learned the local system. Emplacement of the battery and preparation of fire would have been more rapid and accurate if a coordinated procedure for firing had been employed.

67. Comments of Battalion Commanders on Drill Procedures. The following comments are based on replies of 46 battalion commanders to a questionnaire[1] on drill procedures:

a. Twenty-two stated that prescribed drill procedures are satisfactory and recommended no changes.

b. Nine stated that prescribed drill procedures are not entirely satisfactory because no provision is made for a drill for the minimum alert crew.

c. Seven stated that there was a need for a coordinated procedure for the battery as a whole.

68. Conclusions and Recommendations.

a. Conclusions:

(1) Prescribed drills were used only as guides in the European Theater, but as guides they were generally satisfactory.

(2) Insufficient experience prevents drawing conclusions concerning the worth of salvo fire. The use of proximity-fuzed ammunition eliminates the need for this type of fire.

(3) There is a definite need for coordinated battery drills for emplacement and for conduct of fire.

(4) There is a need for a minimum manning crew drill.

b. Recommendations: It is recommended that:

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1. P 37 Bibliography Par 12.

(1) Current drill procedures be revised to incorporate use of proximity-fuzed ammunition,

(2) A minimum manning crew drill be prepared,

(3) A coordinated battery drill for emplacement be prepared,

(4) A coordinated battery drill for a conduct of fire be prepared, and

(5) The War Department issue field manuals covering all pertinent drills.

CHAPTER 7

MAINTENANCE

69. General. Maintenance methods employed in the European Theater were adequate and practical in the field. They were founded on War Department doctrine which is sound, comprehensive, and sufficient. No considerable difference existed between units in technique of maintenance, even though improvisation had to be resorted to frequently on account of the general shortage of spare parts. The supply of spare parts and the state of training of maintenance personnel were the two main factors which influenced the results of maintenance work.

70. Motor Vehicle Maintenance was the greatest of all maintenance problems. A study of answers to questionnaires submitted by battalion commanders of antiaircraft artillery units employed in the European Theater reveals that battalion maintenance personnel were adequate, and that shortage of spare parts kept vehicles deadlined longer than would have been necessary had sufficient parts been available.[1] The shortage of spare parts necessitated increased attention to motor maintenance. Therefore, maintenance by drivers was vigorously stressed and supervised to insure its being carried out, and 1,000 and 6,000 mile inspections were made despite severe tactical conditions. Many units gravitated toward task systems in attempts to provide adequate maintenance for all vehicles at the proper time and to insure close supervision and inspection. One such system, developed by a brigade motor transportation officer, based on the British idea of tasks, and reviewed by an ordnance maintenance company, proved successful and outstanding. The procedure provided that certain tasks would be done every day and that a 14-day cycle would insure the adequate and proper maintenance of each vehicle. This method was employed by the brigade and by its attached units; the method provided a means for continued and adequate maintenance. However, the majority of units depended upon the American maintenance concept of first echelon (or driver) maintenance, backed by published doctrine on second, and higher, echelon maintenance. War Department literature on the subject is adequate and sound. Unsatisfactory motor-vehicle maintenance was invariably caused by shortages of spare parts and not by inadequacy of maintenance methods.

71. Artillery Maintenance Methods. Antiaircraft artillery units almost universally used the same artillery maintenance methods. Gun batteries and individual automatic weapons were put out of action for daily maintenance in accordance with a fixed and supervised schedule. Assigned maintenance tasks were performed by individuals or groups, using prescribed check-sheets to insure thoroughness. Close supervision was exercised and frequent inspections were conducted. War Department publications cover service of the piece of the various antiaircraft artillery weapons and carriages, and the check lists and maintenance procedures prescribed in these publications are adequate and sound. In general, they were followed by units in the field. Where variation occurred, it consisted usually of the employment of a modified check-sheet to include additional items of maintenance found or believed to be necessary on account of vigorous field conditions. No need for changes in current War Department publications is indicated.

72. Maintenance of Fire Control Systems. Maintenance of fire

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1 P 37 Bibliography Par 12.

control systems, especially for heavy antiaircraft artillery units, followed the same pattern as for artillery. Fire control systems were maintained while the batteries were out of action for daily maintenance, or immediately when defects appeared. Signal radar maintenance units, provided in an average ratio of one per two gun battalions, were instrumental in the attainment of high radar maintenance standards despite periodic shortages of spare parts. Qualified replacements for technical repairmen were lacking, but otherwise, battalion maintenance personnel, assisted by signal radar maintenance units, were adequate. War Department publications are adequate on service of fire control systems and were generally followed by units in the field. Improvisation was resorted to upon occasion in order to increase efficiency. Improvisations were caused either by a shortage of spare parts or by the absence of a standard piece of equipment desired, and were not due to any inadequacy in published doctrine on maintenance of fire control systems.

73. Maintenance of Communication Equipment. No particular method of maintenance of communication equipment was used by antiaircraft artillery units in the field. In general, radio equipment was maintained by replacement of parts and through repair work performed by repairmen as defects occurred. Generators were serviced by communications personnel under supervision of technical motor personnel. Aside from the motor generators and auxiliaries, which must be periodically inspected and serviced, communications equipment does not lend itself to a rigid check system. Service of wire and radio equipment is adequately discussed in War Department publications. No new technique in the maintenance of this equipment was developed in the European Theater that warrants a change in published doctrine.

74. Maintenance of Individual Equipment and Small Arms. Individual equipment and small arms were cared for by individuals. Frequent inspections insured that proper maintenance was being performed. Replacement was effected by exchange through organization supply. Maintenance of individual equipment and small arms was generally satisfactory, and no new technique was developed which would indicate changes in War Department publications.

75. Conclusions and Recommendations.

a. Conclusions:

(1) Within limitations imposed by shortages of spare parts, maintenance in the European Theater was adequate.

(2) With relatively minor exceptions, maintenance was performed in accordance with existing War Department doctrine.

b. Recommendation. No change in existing War Department doctrine on maintenance is recommended.

CHAPTER 8

METEOROLOGY

SECTION 1

PROCEDURE FOR OBTAINING DATA

76. Development of Technique.

a. In the fall of 1943 antiaircraft artillery and weather service personnel in the European Theater conducted a series of tests to devise suitable methods for determining meteorological data for the use of air force and antiaircraft artillery units.

b. While considerable experimental work had been conducted in the United States prior to the tests conducted in the European Theater, no standard doctrine had been published, and antiaircraft units arriving in the European Theater had been trained in obsolete methods. No system for determining winds aloft under conditions of poor visibility had been taught to units in training, and the determination of densities by radiosonde[1] had not been standardized. The development of a suitable technique in the European Theater overcame these deficiencies. This procedure included the use of certain Air Force equipment.

c. The experiments resulted in the standardization of a technique for determining meteorological data, which, so far as it pertained to antiaircraft artillery units, was published in a training memorandum by the Antiaircraft Section of the European Theater during April 1944.[2] The memorandum was used as a guide by all units throughout the war.

77. Determination of Winds.

a. Determination of ballistic winds for the use of artillery and true winds for use of air forces was the responsibility of antiaircraft artillery gun units. The technique developed was called the Rawin method. Observations in accordance with the technique adopted were, in general, made four times daily. The usual practice was for the antiaircraft artillery brigade to delegate the responsibility for making these observations to two gun battalions for a period of about one month. The battalions would arrange either to alternate balloon ascents or to pool their meteorological personnel.

b. Because of the variation of winds over space and time, every effort was made to insure that meteorological messages contained recent wind data and that data were taken within 25 miles of the unit for which they were intended. On account of difficulties in dissemination of information and an inadequate supply of meteorological materials, these efforts were not always successful.

78. Determination of Densities.

a. Determination of ballistic densities for use by artillery

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1. Rawin and radiosonde are discussed in TM 20-240.
2. P 38 Bibliography Par 21.

units was the responsibility of the detachments of the 21st Weather Squadron attached to ground force units. First United States Army had two detachments equipped with radiosonde; all other armies and IX Air Defense Command each had one such detachment.

b. The normal procedure was to make four radiosonde ascents daily, corresponding to the four Rawin determinations. A shortage of supplies, however, limited the number of ascents for each detachment to two daily during certain periods. The supply shortage and the small number of radiosondes available, coupled with the usual communication difficulties, resulted in unsatisfactory density information for antiaircraft artillery units. The 55th Antiaircraft Artillery Brigade reported that 40 percent of their meteorological messages did not include weather service data.[1]

SECTION 2

DISSEMINATION OF METEOROLOGICAL INFORMATION

79. Systems Used in Static Defenses. On account of the relatively well-established communications systems in rear areas, no particular difficulties arose in the dissemination of meteorological information in rear area defenses. In Antwerp, for example, the antiaircraft artillery unit obtaining wind data and the weather detachment each telephoned its respective part of the meteorological message to the antiaircraft operations room. The parts were there combined and transmitted over the operations room telephone network as a complete message. The IX Air Defense Command procedure differed in that the information was combined by the weather detachment and the complete message was furnished the antiaircraft operations room for dissemination. No particular difficulty was encountered in either system.

80. Systems Used in Mobile Situations.

a. During periods of great fluidity, communications were so difficult that weather detachment data did not reach the using antiaircraft unit.[2]

b. The system used by Third United States Army units is believed to be typical of the methods used by all the armies. Initially, units determining Rawin data reported their information to the weather detachment on a meteorology radio net, and all gun battalions received the completed message from the weather station on the same net about 30 minutes later.[3] Since this system required taking the battalion radio set SCR-177 off its normal mission for a considerable period four times daily, the system was not satisfactory. In order to return the SCR-177 to its normal command net this system was later changed and transmissions were made over the group-battalion net of the battalion which was computing the Rawin data. The group received the data and relayed to a net control station (actually a designated army antiaircraft artillery group) which relayed the data to the 21st Weather Squadron detachment. The Squadron completed the message and sent it to the group net control station, from which it was relayed to other antiaircraft artillery groups, which, in turn, relayed it to gun battalions.[3] The system obviously

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1. P 38 Bibliography Par 22.
2. P 37 Bibliography Par 12.
3. P 38 Bibliography Par 23.

involved too much relaying of messages. The final and most workable solution was reached only after non-standard radio equipment was obtained which insured reliable communication between gun battalions and the army antiaircraft operations room. The battalion determining ballistic winds and the weather detachment both reported their parts of the message to the operations room, where the data were combined and the complete message broadcast to the using battalions.

SECTION 3

ORGANIZATION OF METEOROLOGICAL SECTIONS

81. Present Organization. Current tables of organization provide four men in the headquarters battery of the gun battalion for a meteorological section.

82. Inadequacy of Personnel.

a. Normally ten men are required in making a Rawin determination, to perform duties as follows:

(1) Three radar operators, including range and altitude reader.

(2) Four at the tracking head to track the target until lost visually and to read azimuth and elevation.

(3) Three to act as time-recorder, computer, and plotter, respectively.

b. In addition to the highly technical task of taking readings on balloon flights and calculating data from ascents, other tasks of a laborious and time-consuming nature had to be performed by the section, such as preparation of hydrogen, balloons, and reflectors.

c. The personnel problem was partially solved by borrowing men from other sections, pooling meteorological sections of two battalions and dividing the Rawin ascents among several battalions. Battalions operating alone acutely felt the personnel shortage.[1]

83. Consideration of Establishing a Meteorological Section with the Antiaircraft Artillery Group.

a. In a normal situation there will be several gun battalions within an area where a single Rawin determination can serve all the battalions. In such situations battalions could be served by a single meteorological section at group or comparable level.

b. With the advent of radar-controlled fire for automatic weapons it is considered likely that all antiaircraft artillery will require meteorological data. It is, therefore, considered uneconomical in personnel and material to maintain an adequate meteorological section in each battalion.

c. The chief disadvantages of placing the section with the group or comparable unit is the requirement for an additional radar.

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1. P 37 Bibliography Par 12.

However, by employing a simple transponder in the ascending balloon, a compact low-powered ground station would be adequate.

SECTION 4

COMPARISON WITH WAR DEPARTMENT DOCTRINE

84. General. As indicated in Section 1, procedures for the Rawin-radiosonde determination of meteorological data were established in the European Theater in April 1944. The then current manual on meteorology for artillery, Technical Manual 4-240, was obsolete. Present War Department doctrine on meteorology is contained in Technical Manual 20-240, which was published in November 1944. As the techniques developed in the European Theater had proved satisfactory, little change occurred upon the receipt of the new manual. In certain details the War Department procedures differed from those used in the European Theater. These differences are discussed in the following paragraphs.

85. Wind Determination. The normal procedure employed included the following deviations from methods prescribed in Technical Manual 20-240:

a. A time-interval method of taking readings was used rather than the altitude-interval prescribed in Technical Manual 20-240. The time-interval method is considered advantageous where wind determination for both artillery and weather service use is required.

b. Azimuths and elevations were generally read at the tracking head rather than at the radar, as prescribed in Technical Manual 20-240. This procedure provided more accurate data.

86. Density Determination. Radiosonde densities were not corrected for the effect of cloud and rain, as suggested in paragraph 32 of Technical Manual 20-240. Replies of antiaircraft artillery commanders to a questionnaire[1] did not indicate that a preponderance of shorts occurred during cloudy or rainy conditions; however, it is not believed that sufficient evidence was obtained to draw conclusions from these replies.

87. Form of Message. The ten-digit form, including ballistic temperatures, as prescribed in Technical Manual 20-240, was not employed. The old seven-digit form was usually modified to include densities to the nearest one-tenth of one percent.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

88. Conclusions:

a. Procedures developed in the European Theater were satisfactory and had certain advantages over the methods prescribed in Technical Manual 20-240.

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1. P 37 Bibliography Par 12.

b. Antiaircraft artillery units did not receive adequate information from weather service detachments.

c. Insufficient personnel are provided for the battalion meteorological section.

89. Recommendations: It is recommended that:

a. Technical Manual 20-240 be revised,

b. The present meteorological section be deleted from gun battalion organizations,

c. Appropriate equipment be designed and issued for the purpose of preparing complete meteorological messages by one and the same section, and

d. An adequate meteorological section capable of preparing complete meteorological messages be included in the antiaircraft artillery group or comparable organization.

CHAPTER 9

FINAL CONCLUSIONS AND RECOMMENDATIONS

90. Conclusions:

a. The movement and deployment procedures published by Headquarters, European Theater of Operations, were proven by extensive tests to be excellent guides to the reconnaissance, selection and occupation of positions by antiaircraft artillery units.

b. War Department doctrine on communications for antiaircraft artillery units needs thorough revision to permit continuous operation and the application of modern technique.

c. The current War Department doctrine on antiaircraft artillery fire direction is inadequate.

d. Rules for engaging aircraft in the European Theater were too voluminous and too complex.

e. Improvement in equipment, incorporating adequate search features and insuring positive identification of aircraft by fire units, would have permitted simplification of rules for engagement and removed many restrictions on flying.

f. Present fire control equipment for automatic weapons is unsatisfactory.

g. Barrage fire by automatic weapons is justified when controlled, but the necessity for barrage fire will disappear when suitable fire control methods are adopted.

h. Ammunition issued in the European Theater was of so many different lots of varying characteristics that it produced great dispersion.

i. A need exists for War Department publication of drill procedures for minimum manning of "stand-by" crews.

j. Current doctrine on maintenance is adequate.

k. Published procedures for obtaining meteorological data need to be revised.

l. Trial fire, as accomplished according to War Department doctrine, was useful for check-fire.

m. Time fire registration according to Field Manual 6-40 is not applicable to flat-trajectory, high-velocity weapons.

n. Firing one battery by present position data received from another battery was not practiced and is not necessary.

o. Barrage fire by 90 millimeter guns is not desirable.

p. Insufficient experience prevents drawing conclusions concerning the worth of salvo fire. The use of proximity-fuzed ammunition eleminates the need for this type of fire.

91. Recommendations: It is recommended that:

a. Communications be completely revised and technique therefor be published in field manuals;

b. A system of positive identification, friend or foe, be developed and used by antiaircraft artillery units;

c. An adequate search instrument be developed to enable fire units to detect targets and to direct fire control instruments to any specified target;

d. Rules for engagement of aircraft be standardized for all theaters and published in War Department field manuals;

e. Radar fire control equipment for automatic weapons larger than 20 millimeter be developed with the following characteristics: mounted on the same carriage with the weapon; operated by one man; small in size and light in weight; capable of detecting aerial targets at 30,000 yards slant range and from zero to 85 degrees in elevation; capable of accurate automatic tracking; computation of firing data and gun laying for firing at unseen targets on any type course at speeds up to 1,000 miles per hour;

f. An on-carriage computing sight, operated by one man, capable of tracking aerial targets at speeds up to 1,000 miles per hour, and not requiring any element of firing data to be estimated, be developed for automatic weapons smaller than 37 millimeter guns;

g. All automatic weapons be equipped with suitable sights for terrestrial fire, direct and indirect;

h. Ammunition of standard characteristics be furnished;

i. Doctrine include trial fire as consisting of firing on two or more points;

j. Field chronographs and timing devices be adopted as organizational antiaircraft artillery equipment;

k. Technique be developed for time registration of flat-trajectory, high-velocity guns;

l. Plans for firing one battery by present position data received from another battery be abandoned;

m. Barrage fire not be used by gun units;

n. Current drill procedures be revised to incorporate procedures for all standard fire control equipment;

o. A minimum manning crew drill be prepared;

p. Coordinated battery drills for emplacement and for conduct of fire be prepared and included in field manuals on drills;

q. The technique of obtaining meteorological data (Technical Manual 20-240) be revised;

r. Appropriate equipment be designed and issued for the purpose of preparing complete meteorological messages by one and the same section;

s. The present meteorological section be deleted from gun battalion organizations, and

t. An adequate meteorological section capable of preparing complete meteorological messages be included in the antiaircraft artillery group or comparable organization.

ANTIAIRCRAFT ARTILLERY TECHNIQUES

PART THREE

BIBLIOGRAPHY

Note: Unless otherwise indicated, documents are located in the files of the AAA Section, The Theater General Board, APO 408.

1. Pamphlet, "Movement and Deployment Procedures, AAA Guns," Hq ETOUSA, 15 March 1944.

2. Pamphlet, "Movement and Deployment Procedures, AAA Automatic Weapons," Hq ETOUSA, 22 February 1944.

3. Pamphlet "Movement and Deployment Procedures for AAA, AW, Self-Propelled", Hq ETOUSA, 1 May 1944.

4. Appendix I, Resume of statements and opinions of battalion commanders considered in the preparation of Chapter 2, and percentage votes for and against adopting as standard the Movement and Deployment Procedures taught in the European Theater.

5. Field Manual 44-2, December 1944, Employment of Antiaircraft Artillery, Automatic Weapons.

6. Field Manual 44-4, June 1945, Employment of Antiaircraft Guns.

7. Appendix II, Antiaircraft Artillery Communications Equipment and Personnel.

8. Operations Memorandum No. 7, SHAEF, 9 March 1944.

9. 12th Army Group AAA Notes.

10. SHAEF Air Defense Reviews.

11. Air Defense Instructions, SHAEF, 15 December 1944.

12. Antiaircraft Artillery Questionnaires, Hq ETOUSA, 11 June 1945.

13. Appendix III, Operations "Blankcheck".

14. AGF Observers Report No. 796, Answers to Questionnaires.

15. Letter, Subject: "Comment on Weissight (Computing Sight, M-7)," AGF Report 167.

16. Appendix IV, Extracts from a Study of American Antiaircraft Equipment, 71st AAA Group.

17. Azimuth and Elevation Indicators for 40mm guns, AAA Notes

No. 22, Hq ETOUSA, 21 March 1945.

18. Unit Factual Data obtained from replies to Letter Hq ETOUSA (AG 472 Op AA), Subject: "Antiaircraft Artillery Questionnaire", dated 11 June 1945 from the following AAA Gun Battalions:

112th	602d	118th	133d
113th	605th	119th	134th
114th	740th	120th	135th
167th	749th	124th	136th
405th	68th	125th	141st
407th	72d	126th	142d
414th	108th	127th	143d
494th	109th	128th	184th
495th	110th	129th	214th
519th	115th	131st	216th, 217th and
601st	116th	132d	413th

19. Annex D, Report 2F, Hq Antwerp X, dated January 1945.

20. Drill for 40mm Fire Units, AAA Section, Hq ETOUSA, 19 July 1944.

21. Memorandum, Hq IX Air Defense Command, Subject: "Operations, Meteorological Data," 20 July 1944.

22. Interim Report, Hq ETOUSA, Subject: "Observations on the Use of TM 20-240, Meteorology for Artillery," 10 May 1945.

23. Operations Memorandum No. 29, Hq 38th AAA Brigade, 18 November 1944, and Change 1, 3 January 1945.

Resume of statements and opinions of battalion commanders considered in the preparation of Chapter I, and percentage votes for and against adoption as standard of the movement and deployment procedures taught in the European theater.

Number of statements considered	-	112
Number not familiar with the procedures and having no comment	-	26
Number for adoption as standard and incorporation in W. D. publications	-	63
Number against adoption as standard	-	13
Number for adoption with modifications and incorporation as a guide only	-	10
Percentage (of those units familiar with the procedures) for adoption as standard and incorporation in W. D. publications	-	73%
Percentage (of those units familiar with the procedures) for adoption with modifications as standard, or adoption as a guide only	-	12%
Percentage (of those units familiar with the procedures) against adoption as standard	-	15%

APPENDIX II

ANTIAIRCRAFT ARTILLERY COMMUNICATIONS

EQUIPMENT AND PERSONNEL

RADIOS

	Command Nets	Intelligence Nets
Brigade	1 SCR-177 (up) 1 SCR-177 (down)	2 SCR-543 (one spare)
Group	1 SCR-177 (up) 1 SCR-177 (down)	1 SCR-543 (no spare)
Battalion, Gun	1 SCR-177 (up) 1 SCR-543 (down)	1 SCR-543
Battery, Gun	1 SCR-543 (up)	1 SCR-593 (receiver)
Battalion, Automatic Weapons, Except self-propelled	1 SCR-177 (up) 1 SCR-543 (down)	1 SCR-543 (control) 6 SCR-543 (observer)
Battery, Automatic Weapons, Except self-propelled	3 SCR-543 (1 in battery, each platoon)	11 SCR-593 (receiver) (1 in battery, 1 each platoon, 1 each section)
Battalion, Automatic Weapons, self-propelled	1 SCR-506* (up) 2 SCR-508 (down) 1 SCR-510 (down) 2 SCR-528 (down)	8 SCR-543* (observer) 1 SCR-593* (receiver) 1 SCR-528
Battery, Automatic Weapons, self-propelled	3 SCR-508 (Platoon) (Battery) 1 SCR-510 (up) 8 SCR-528 (gun sections)	3 SCR-593* (Battery and Platoon)
Operations Detachment	———	2 SCR-177

*Note: In self-propelled units, all radios except SCR-506, -543, and -593 are frequency modulated. Furthermore, in such units the command nets are also for warning.

Each brigade was provided 20 miles of field wire W-110-B; each group, 10 miles; each battalion, except self-propelled, a total of 25 miles; each operations detachment, 50 miles of W-110-B and five miles of W-130. These units were provided telephones, switchboards, reels etc. Self-propelled units were provided no wire communications.

PERSONNEL

A full time communications officer was provided for each brigade and each group; all other units had to assign the communications duty as an additional duty to some officer--usually either the intelligence officer or the operations officer. All units, including batteries, were provided an enlisted communications chief with one or more assistants in some units and all except gun batteries and headquarters of automatic weapons battalions (mobile and semi-mobile) were provided one radio repairman each. Each headquarters above battery was provided one message center chief and group headquarters, only, was provided three messengers. Telephone operators were provided for gun batteries and 40mm gun sections. Other operators and linemen were provided as follows for headquarters and batteries:

	Radio	Switchboard	Linemen
Brigade	6	2	3
Group	7	2	3
Battalion, Gun	5	2	2
Battery, Gun	1	2	2
Battalion, AW (except self-propelled)	4	0	2
Battery, AW (except self-propelled)	2	4	2
Battalion, self-propelled	4	0	0
Battery, AW, self-propelled	5	0	0
Operations Detachment	3	5	5

HEADQUARTERS
38th Antiaircraft Artillery Brigade
APO 403, United States Army

OPERATIONS MEMORANDUM)
:
NUMBER 3)

OPERATION "BLANKCHECK"

1. General. In some instances, it is desirable to give antiaircraft units in an area greater freedom of action than permitted by normal rules for unrestricted area, while at the same time, it is impracticable to constitute the area an IAZ. This has been made possible by an agreement reached between the Antiaircraft Officer, Third US Army and the Commanding General, XIX Tactical Air Command. The agreement in principle is, that, during limited periods when the Controller is positive that no friendly planes will appear in the designated area, planes appearing within the area may be engaged without the necessity of positive recognition or hostile acts. This is referred to as operations "Blankcheck".

2. Method of Operation.

a. Prior agreement must be reached with higher headquarters and notice given from this headquarters before the "Blankcheck" operation can be applied to a given area.

b. Once an area has been approved, the decision to place "Blankcheck" in operation in specific instances will be the responsibility of the Controller at the XIX Tactical Air Command, Fighter Control Center.

c. Upon being authorized by the Controller, the AA Liaison Officer will broadcast "Blankcheck" instructions over the AA frequency. "Blankcheck" instructions will be acknowledged. The area will be designated using the "Hold Fire" number as given in change 4 to operations Memorandum #24, this headquarters, dated 15 January 1945. In the event the area is not among those listed, it will be designated using the AAA radio call sign of the unit involved such as Able 17 or Able 20 (this method has been used up to now). A time limit will be specified. Planes to be engaged must be within a radius of 12000 yards of the center of the area. An altitude limit or ceiling may or may not be specified. If not specified, planes at any altitude may be engaged.

d. Examples:

(1) "Blankcheck 04-2300 - 10,000"

This means that units in area 04 are released to engage planes below 10,000 feet without recognition from time of receipt until 2300 hours provided they are with in the 12000 yard radius. The "Blankcheck" automatically terminates at 2300 hours.

(2) "Blankcheck 446 - 2300"

This means that units may engage planes without recognition at any altitude when within a 12000 yard radius of the center of the area occupied by the Headquarters, 546th Battalion from time of receipt until 2300 hours.

3. Rules for Engagement.

a. During periods of Blankcheck rules for engagement are the same as those for an LZ as set forth in OM #14, Third US Army.

b. At all other times, rules are those for an unrestricted area as set forth in OM #14, Third U. S. Army.

4. Emergency Provisions.

a. If two way communication should fail during a "Blankcheck" period, the area reverts to an unrestricted area at once even though the time limit of the "Blankcheck" may not have expired.

b. If a friendly flight should unexpectedly appear during a "Blankcheck" period, Pincushion and Mainscheck will be used to hold fire in the usual manner. After Mainscheck the area continues in a Blankcheck status until the time limit expires.

By Command of Brigadier General HINES:

W. H. ALLEN, Jr.,
Major, G.S.C,
Adjutant.

OFFICIAL:

/s/ W. H. ALLEN, Jr.,
/t/ W. H. ALLEN, Jr.,
Major, G.S.C,
Adjutant.

EXTRACTS
FROM
A STUDY OF AMERICAN ANTIAIRCRAFT EQUIPMENT
BY
71st ANTIAIRCRAFT ARTILLERY GROUP
COLONEL F. W. LEWIS, COMMANDING

7. Radar for the 40mm. Experiments were conducted to solve the problem of fire control for automatic weapons more efficiently by the introduction of a radar unit, the T-35. The unit is composed of three major pieces of equipment; the tracking head, power regulator, and computor. This equipment was designed to be operated either from separate dug in emplacements or from one van. The first three weeks of the experiment two 40mm guns were used, although later only one gun was employed. The only modification necessary for the gun was the installation of the M-3 oil gear. Actually, the fire control equipment may be used to control one, two, three, or four guns.

a. In order to fully understand the experiment, some emphasis must be placed on details of the equipment.

(1) The tracking head contains a radar transmitter and receiver, and azimuth and elevation telescopes for optical tracking. It resembles the M-5 director in appearance and weighs 600 pounds.

(2) The power regulator contains circuits for converting 120 volts three phase power to 300 volt regulated DC, 480 volt unregulated DC and 6½ volt regulated DC, all of which are necessary for the operation of the computor. Weight of power regulator is approximately 575 lbs.

(3) The computor, which has maximum range capabilities of 17000 yards, contains radar indicator and the necessary circuits for computing information to be supplied to guns, future azimuth and elevation. It is fully ballistic, designed to give an accurate solution to the Fire Control problem. Although devices are present for adding azimuth and elevation spots up to 50 mils, normally it was operated with no spots being applied. Provisions are also made for setting in wind velocity and direction, air density, muzzle velocity, and parallax to 50 yards between gun and tracking head in each of three coordinates. Weight of the computor is 650 pounds.

b. A minimum of seven men are required for efficient operation. This includes three men on the tracking head, an azimuth and elevation tracker and one man, the controller, to slew the instrument on the target initially. One radar range tracker operates the computer. Three men are necessary on the gun; gunner, loader, and firer; and one ammunition relayer. When a target appears, it is first picked up by the trackers visually and the report "on target" is given by phone to the range tracker who also begins tracking the target as soon as it appears on his scope. When target positioning data has become steady (from 3 to 12 seconds), "on target" is given by phone to tracking head. Ranges are read out intermittently to controller on tracker and when range reaches 4500 yards, a signal is given chief of section who orders fire when

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desired.

c. Thirty targets were engaged, nineteen of which may be considered valid for test data. Technicians define an invalid course as being one on which equipment was improperly operated, making accurate prediction impossible. These courses were due largely to inexperienced and untrained operating personnel. On the nineteen valid courses, 317 rounds of ammunition were fired. A total of two "Category Ba" were claimed, although damage to "Divers" could not be estimated accurately due to other guns firing on the same target.

d. There were difficulties encountered in operation which, it is believed, could be eliminated in time.

(1) The first problem confronting the experimental unit was that of untrained radar operators, and a SCR-584 operator had to be used. However, the two radars differ in operation, and experience in the T-35 was found to be necessary.

(2) Difficulty was encountered when too much time was consumed by the radar tracker in setting the proper ranges for a "Diver" after it had been picked up by visual trackers. This made it very difficult to engage fast targets tracked under 4,000 yards. As ability in picking up targets varies directly with visibility, many targets were lost due to trackers being unable to get on target sufficiently early to permit an engagement.

(3) The greatest problem presented technicians, was that of ballistics. It is impossible under field conditions to know meteorological and ballistic data of ammunition close enough to warrant the use of point detonating ammunition at intermediate ranges. Variations in powder lots of ammunition, wear of tube, powder temperature, weight of projectile, etc., also contributed to the ballistic problem. In order to illustrate the major importance of ballistics, the table below is presented. It is a table of required accuracy of differential effects to cause a miss of two yards in elevation and five yards in azimuth for targets crossing at 4,000 yards and at 2,000 yards, travelling in each case at 200 yards per second.

	Crossing at 2000 yds		Crossing at 4000 yds	
	Elevation	Azimuth	Elevation	Azimuth
Cross Wind		13 MPH		2.7 MPH
Head Wind	7.7 MPH	15.4 MPH	2 MPH	5.1 MPH
Muzzle Velocity	49 ft/sec	22 ft/sec	9.8 ft/sec	8.5 ft/sec
Air Density	5%	3.1%	.75%	.57%

(a) With the T-35, it was impossible to make a correction in air density for smaller than 1½% or for muzzle velocity less than 15 ft/sec.

(b) The use of spots had been discouraged for several reasons:
The radar range tracker is busy following the target.