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THE DEVELOPMENT OF GERMAN ANTIAIRCRAFT WEAPONS AND EQUIPMENT OF ALL TYPES UP TO 1945

by

General der Flakartillerie a.D. vonRenz

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PREFACE

When requested to compile a study on the subject dealt with in this present volume at the end of 1957 I accepted the assignment because of the realization that there are unfortunately only very few officers still alive who had been closely connected with the old German antiaircraft arm since 1913 and whom many years of service in the pertinent military-technical offices provided an insight into the whole complex involved equal to my own.

I fully realize that my work also will not be perfect and complete and that some of the views offered are one-sided. Drawing on my personal experience, however, I have endeavored to contribute towards continued successful work in the field of antiaircraft weapons and operations. The criticisms I express at times are not intended merely for the sake of criticising, but are designed exclusively to point up lessons for the future.

My desire is that my work my provide future workers in this field of endeavor with a knowledge of past mistakes and successes, which they may use as a foundation for continued and successful work.

In Appendix 1 I am including a brief review of my own military career from which it is possible to trace the essential basis on which my work is founded.

S/ von Renz
Karlsruhe/Baden, 1958 Lt. Gen AAA (Retired)

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In the work which follows, the role played by the several military-technical offices and other agencies in the development of antiaircraft weapons is given appropriate treatment. The agencies concerned are as follows:

The Artillery Proving Commission (Artillerie-Pruefungs-Kommission up to 1919

The Weapons and Equipment Inspectorate (Inspektion fuer Waffen und Geraet), 1919-1925

The Army Ordnance Office/Proving Branch/Weapons Proving Section (Heeres-Waffenamt (Pruefwesen) (Wa.Pruef.)),1925-April 1935

The Army Ordnance Office, Branch 10-AAA, 1 May 1935-1940

The German Air Ministry/National Defense Office/ AAA (Reichsluftfahrt-Ministerium L/Flak E),1940-June 1942

The Office of the Chief of Air Forces Special Supply and Procurement Service/AAA Development Group (General-Luftzeugmeister Amtsgruppe Flakentwicklung), June 1942-September 1944

The Office of the Chief of Technical Air Armament/AAA Development Group (Chef technische Luft-Ruestung Amtsgruppe Flakentwicklung), September 1944-May 1945.

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CHAPTER ONE

THE GERMAN ANTI-BALLOON ARM

1906-1914

1. Anti-Balloon Weapons Prior to Outbreak of World War I in 1914. As early as in the Franco-Prussian War of 1870-71 the firm of Krupp manufactured and delivered specially constructed guns which were used against the free balloons employed by the French enveloped in Paris to maintain contact with the territories not occupied by German troops. These weapons were 37-mm pivot-mounted guns placed on 4-wheeled wagons.

Around the turn of the century the first promising results were obtained in flights with dirigible balloons, airships and heavier-than-air aircraft, including the first zeppelin to cross Lake Constance on 2 July 1900 and the first flight by the Wright Brothers with a maneuverable airplane. In October 1905 an airplane for the first time flew a distance of 38.9 kilometers (roughly 24 miles).

The first step had thus been taken on the way to the military use of air ships and heavier-than-air aircraft. As a logical consequence the Prussian War Ministry early in 1906 instructed the Artillery Proving Commission to investigate to what extent the existing field and foot artillery guns were suitable for action against airships and other aircraft. Already

4 in April of the same year the Commission submitted a report calling for the development of special types of guns for action against airships.

The firms of Erhardt (Rheinmetall) and Krupp, both in Germany, had on their own initiative already concerned themselves with the problems involved. At the 1906 Berlin Auto Exhibition, for example, the firm of Rheinmetall demonstrated a swivel-mounted gun on a lightly armored car; this was a long-barrelled Model L/30 50-mm gun designed for anti-airship fire (Photo 1). Mounted on the armored car the gun had a 60° field of traverse. Designs also provided for the gun mounted on an unarmored car with a 360° field of traverse. It had a total movement of elevation ranging from minus 5° to plus 70°. Firing normal shells the muzzle velocity was 572 m/sec. firing shrapnell shells 450 m/sec. The idea was to follow the target and take it under fire from a suitable angle and range, so that the provision of armor-plate protection for the gunners seemed justifiable.

In 1908 the firm of Krupp exhibited a 65 mm gun, Model L/35 on a wheel mount with slewable wheels (Photo 2). The gun had a 60° total movement in elevation and could be slewed by the wheels to give a 360° field of traverse.

Under instructions from the War Ministry experimental firing had already been conducted along the coast in March

1907 at free balloons and at balloons towed by ships. In these
5 tests the field artillery models F.K.96 (Close-Range) and light
field howitzer 98, and the foot artillery model K.04 with a
caliber of 100 mm., were used.

The results of these tests confirmed the necessity stated by the Artillery Proving Commission in April 1906 for a special type of gun. What became conspicuously evident was the unsuitability of the Model F.K. 96 (Close Range) field gun with its box-tail gun carriage , which permitted an elevation movement of only 18°. This meant that, unless the gun carriage tail was dug into the ground, the gun had a maximum firing altitude of only roughly 1500 feet. For these obvious reasons, this gun was cancelled from the program and preference was given to the models with a possible elevation movement of 40° and more. In spite of the small speed of the targets, however, the rate of lateral traverse was by no means adequate. In those days computations were based on a maximum airship speed of 10 meters/second and a maximum operating altitude of 4,000 feet.

However, the War Ministry considered the action which could be taken with existing weapons against airships was still adequate The only requirement it stated, on the basis of test firing against targets in the air, was that the batteries should be authorized a range finder among their standard equipment. The tests had shown, namely, that the conventional methods of bracket

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5-6 adjustment fire were not sufficient, since in the air the burst smoke and the target could only very rarely be brought into a relation suitable for range computations. New comparative firing tests were carried out in August 1910, the weapons used being the light field howitzer Model l.F.H. 98/90--meanwhile improved by adaptations as a rapid fire gun; the 100-mm Model K. 04; the 50-mm Model L/30 of the firm of Rheinmetall; and Krupp's 65-mm Anti-Balloon Gun Model L/35. Model F.K. 96 (Close Range) had been removed from the program because of its inappropriate gun carriage.

During the Kaiser Maneuvers of 1910 the same weapons were given a tactical test, together with other test models meanwhile produced by the industrial firms. These new models were

Krupp: Model L/35, 75-mm, on wheel mount;

Krupp: Model L/30, 71-mm, on motor vehicle;

Rheinmetall: Model L/35, 65-mm, on motor vehicle.

The technical data of these weapons were as follows:

<u>Krupp: Model L/35, 75-mm, on wheel mount</u>

Muzzle velocity	510 meter/second
Total movement of elevation	-5° to $+65^\circ$
Effective firing altitude	16,500 feet

Ammunition: Incendiary shell with impact fuze.

Krupp: Model L/30, on motor vehicle (Photo 3):

Muzzle velocity	650 meter/second

6-7 Total movement of elevation 0° to +75°

Effective altitude of fire 21,450 feet

Ammunition: Incendiary shell with impact fuze.

Rheinmetall: Model L/35, 65-mm, on motor vehicle (Photo 4):

XXXXXXXX Muzzle Velocity 670 meter/second

Total movement of elevation +5° to + 75°

Effective altitude of fire 24,970 feet

Ammunition: Shrapnell shell with double-action fuze.

The tests again produced clear proof of the superiority of the swivel or pedestal mounted gun over the gun-carriage mounted types hotherto in use in the artillery forces. Howe ever, the General Staff and the War Ministry still could not arrive at a final decision. They still desired retention of horse traction, arguing that motorized guns would not be able to adjust their speed of movement to that of an infantry division on the march, and would always remain a foreign element in such a division. The problem also still required clarification of how to insure adequate resupplies of fuel.

On the basis of all considerations involved, the following specifications were formulated in October 1910 by the War Ministry, XXXXXX in consultation with the Artillery Proving Commission, for the development of anti-balloon guns:

Caliber and ammunition: as 77-mm Model F.K.96 (Close Range)

Traction: Horse-drawn, on field type gun carriage, weight to e ual that of mounted artillery.

With mechanism for rapid elevation and traverse movement.

On motor vehicle with swivel or pedestal mount.

7-8 The above formulation clearly reveals that every effort was to be made to find a solution using horse traction and not motor vehicles. On the basis of these specifications the industrial firms worked at increased intensity to find a suitable solution, but their efforts were hampered in particular by the demand of the War Ministry and the General Staff for horse traction.

The first solution was that offered by Krupp, involving a 77-mm Model Bak L/27 with the same gun carriage construction as that of the firm's 1908 65-mm Model L/35 gun with slewable wheels. (Photo 5). Rheinmetall sought a solution to the problem of fire against airborne targets by mounting the gun on a wheel base and using the normal howitzer gun carriage, the barrel being that of the Model F.K. 96 (Close Range) (Photo 6) for which reason this gun was later called "the cannon on a howitzer mount". Both guns were delivered and tested in 1911. As in the past the inadequate field of traverse was considered the weak point in both models.

Finally, both Krupp and Rheinmetall in 1912 each produced a gun on a motor vehicle and developed as a swivel mount weapon. This was the solution recommended by both from the beginning and also considered by the Artillery Proving Commission as the only possible solution to the

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8-9 problem of antiaircraft action. Both models showed good performances in the tests (Photos 7 and 8). Nevertheless, both firms received instructions to renew their efforts to find a solution in which the advantages of the pedestal or swivel mount could be exploited for antiaircraft guns mounted on wheels.

Krupp tried out an entirely new design in which the gun ~~[illegible]~~ was anchored to a pole-shaped spur serving as a pivot around which the entire gun could be slewed. Another new departure in this design was the separation of the elevating mechanism for site slope from that for the tangent of elevation. The movement of elevation achieved with this model was from -10° to + 70° (Photo 9).

Rheinmetall retained its former solution practically unchanged. Since this model also did not meet with approval, however, both firms in mid-1913 were again commissioned to design a wheel-carried anti-balloon gun on the pivot mount principle. Guns designed according to this requirement were submitted for tests already before mid-1914, and this construction was taken over almost unchanged when the 77-mm Model L/35 came into production during the war. One disadvantage here was that pivot had to be collapsed when driving, which meant that five minutes were lost in preparing for fire.

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9-10 The overall weight of the gun was also excessive, and for these reasons this model was not introduced at the time (Photos 10, 11, 12).

In April 1914 the General Staff stated the requirement to procure four motor-vehicle mounted anti-balloon guns for each of the eight army headquarters to be activated in the event of a mobilization. Furthermore, the General Staff called for the activation of a mounted anti-balloon battery for each regular infantry division and for each division of the first and second reserve as well as for each replacement division. When this requirement was stated it had not yet been determined what guns were to be provided for the mounted batteries, and it was August 1914 before contracts were placed for the required number of gun batteries.

At the beginning of World War I in 1914 there were thus only the following anti-balloon guns in existence with the performance capabilities of Model F.K. 96 (Close Range): all had a muzzle velocity of 465 meter/second, a range of roughly 5,900 yards and fired field Model 96 shrapnell shells :

6 motor-vehicle carried anti-Balloon guns
2 pivot-mounted anti-balloom guns on wheels
10 older models of 77-mm L/27 anti-balloon guns on wheels (test models of older types).

In addition the batteries were equipped with each one

10 inverted-image rangefinderwith a base of 1.5 meters, which permitted range-finding up to a distance of 4,400 yards.

The aiming mechanism introduced was a panoramic sight with side vision; and each such mechanism had a special attachment giving the correct target data for altitudes of 1,320 yards.

The latitude and altitude lead had to be estimated by the battery officers on the basis of experience. However, only very few officers had any opportunity prior to the war to fire at airborne targets, so that practically no experience was available in this field, a fact from which artillery fire against airborne targets suffered in the initial stages.

An automatic fuze setting mechanism had also been tested which, according to the way it was set ignited the fuze and thus determined its burning duration, a system based on the French principle. However, this type of fuze setting mechanism was rejected since it would have required the introduction of fuzes differing from those in use in the German military. It was also thought that it would be possible to adhere to the old method of fuze setting by employing an adequate numbe of fuze-setter-gunners.

2. Cooperation by the Military-Technical Academy and the Artillery Proving Commission up to 1914. For the handling of military-technical problems there were attached to the

11 War Ministry as field agencies the appropriate installations, within the Army, such as an engineering corps,+ a rifle proving commission and an artillery proving commission, etc. The officers assigned for service in these agencies had received specialized training in courses at the Military-Technical Academy.

All officers of the Engineer Corps++ and of the foot artillery were detadhed for study at this Academy for one year. From the other arms (Infantry, Field Artillery, etc.) those officers were detached for study at the Academy who volunteered for such training, or shome the appropriate authorities considered particularly suitable for the purpose. The principal subjects taught at the Academy were Mathematics, Physics, Chemistry, Ballistics, Statics, Metallurgy, and Materials Research. Presupposed conditions for participation were technical aptitudes and an interest in the problems involved. Officers who proved particularly suitable during this first course of one year and who were interested in the subjects, could to attend a second and more advanced course, also lasting one year. Most of the officers completing these courses were then employed as instructors at schools for the Engineer Arm or at Ordnance Schools.

\+ Ingenieur Corps: It would probably be better referred to as a Technological Corps, and should not be confused with the engineer services commonly referred to in the US Army as the Engineer Corps or Arm. (Translator).

++ Pioniertruppe: The Army engineer services referred to in the US Army as the Engineer Corps or Arm. (Translator).

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11-12 The mo t gifted of them were probably assigned to the several Proving Commissions, where they served as technical advisers to the War Ministry and the General Staff, which was the reason why the Ministry and the General Staff instructed them to carry out the appropriate technical tests. Their mission was largely to watch foreign technical military journals, to consider recommendations from the various firms, and to test the weapons and equipment developed by these firms for usability by the Army.

Many German firms, among them Krupp, Siemens, Rheinmetall, and the IG Farben Combine had contacts abroad and also worked under contract for foreign countries and were therefore able to submit recommendations and also to accept contracts for the development of German weapons and equipment. In this way the supported the German military and helped to keep German military weapons and equipment abreast of the times.

It was not a mission of the Commissions themselves to design and develop new models. This was a mission of the industrial firms with their designing and constructional bureaus, which had available the necessary expert personnel because of their work for foreign countries and because of the needs of their clients abroad. The firms submitted recommendations, which were considered in mutual

12-13 discussions , or they submitted test models, which were then available for proving. On the basis of the data thus acquired, the Commissions then examined the possibility of introduction of new models b the German military forces and submitted their ~~its~~ recommendations to the Ministry and the General Staff. Requests coming from the field forces, or from the General Staff or the Ministry, for new types of equipment were submitted to the appropriate firms, which were then commissioned to design and develop the item required, which they usually did on their own responsibility, and to submit their results.

At the beginning of the war in 1914 the Military Technical Academy and the Artillery Poving Commission and other such bodies were deactivated and the officers serving on their staffs were assigned posts in the field requiring a technical background and which appeared particularly important. For example, such officers were assigned to take over the 420-mm batteries being tried out at the time.

Insofar as they were not also required in the field, the professors serving in the Military Technical Academy were used in advisory posts by the War Ministry.

The fatefully harmful consèquences of these

13 deactivations will become evident later in this study, but it can be said here that the measure was a sign of the lack of understanding for technical problems among those responsible. The only possible explanation is that the responsible authorities andticipated a war of short duration and considered that the weapons and equipment already introduced for military purposes showed adequate performances for such a war. No thought whatever was given to the possibility of creating new weapons or even to the necessity to improve existing models. Also, no thought was given to the fact that the raw materials required for resupply could not be made available from sources within Germany.

The later chapters of this study will reveal how mistaken the measure deactivating the Commissions and other bodies was, and what important missions they were required to execute later in the war.

CHAPTER TWO

THE GERMAN ANTIAIRCRAFT ARTILLERY IN WORLD WAR I
1914-1918

1. The Anti-Balloon Arm during the War, 1914-1916. At mobilization in 1914 the eight horse-drawn experimental guns were committed by platoons in accordance with plans as follows:

at the Duesseldorf Rhine River bridge
at the Mannheim Rhine River bridge
at the Friedrichshafen zeppelin works
at the Metz zeppelin hangars.

The six motor-vehicle carried guns were assigned separately, one each to the Fourth, Fifth, Sixth and Eighth Armies and two to the Seventh Army.

Zeppelins, and even more particularly aircraft, at the time were employed exclusively for reconnaissance purposes, and the few anti-balloon guns available could do nothing whatever to interfere with these activities, even when the units carried out their reconnaissance flights at very low altitudes. On the other hand, it must be admitted that the German Army was the only one which had any anti-balloon guns all at the beginning of the war.

During the strategic concentration of forces, the individual armies posted their six motor-vehicle guns to protect the targets they considered particularly important. The units on line at the front had to make their own extemporary arrange-

15 arrangements insofar as they did not restrict themselves to the use of rifles and machineguns in their unequal combat against the airplanes.

Contracts were only awarded in August 1914 for the construction of approximately 100 batteries of motor-vehicle carried anti-balloon guns, so that it was not to be expected that the industrial firms could within the foreseeable future deliver these guns to the units in the field. The War Ministry therefore requisitioned all anti-balloon guns under construction in German works for foreign countries and also purchased all test models in existence. As a result of these measures

9 motor-vehicle carried anti-balloon guns and
27 horse-drawn " " "

became available in October, of which 22 were allocated to the units on the western front and 14 retained for commitment in the zone of interior.

Already during the strategic concentration, but with growing frequency from October 1914 on, enemy airplanes had commenced firing aerodarts at moving columns and at troops from low altitudes, causing considerable losses in men and horses. As a result, the demand of the units in the field for better protection against air attack became increasingly insistent. However, there was no possibility to obtain new guns from current production and the troops therefore had to help themselves as

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15-16 best they could.

In line with the results obtained in the tests of 1907 to 1914, use was now made of the existing Model F.K. 96 (Close Range) and the light field howitzer model L.F.H. 98/09. Pedestals were constructed to compensate for the inadequate movement of elevation of the F.K. 96 (Photo 13), but in many cases the anti-balloon guns thus produced lacked the most essential item of equipment, a rangefinder. Furthermore, the gun crews had no training whatever in action against airborne targets, and it is therefore not surprising that the chances of hitting a target in the air were very small. Since side and altitude lead had to be computed on the basis of experience, much effort was wasted and large quantities of ammunition were expended without any hope of success. As their first anti-aircraft weapons, ~~XXXXX~~, front line units received the previously mentioned "cannon on howitzer mount" model gun. However, even these were in short supply, since the mounts produced ~~WERE~~ were required for howitzer guns, which were in high repute in the Army because of their great effectiveness. For anti-aircraft fire the howitzers were hardly suitable because of their low muzzle velocity of only 302 meter/second, and they were soon withdrawn from such use.

A large number of captured guns became available already by the end of 1914, and attempts were made to relieve the shortage of anti-balloon guns by using these. The War Ministry

16-17 instructed the appropriate firms to adapt the captured French, Belgian and Russian field guns for anti-balloon fire, the initial plan being to organize a force of 216 such guns, horse-drawn, for the units on line at the front. Each infantry and replacement division and each division of the first and second reserve was to receive an anti-balloon platoon of two guns. In addition 26 of the captured guns were to be adapted for permanent emplacement at targets within the zone of interior.

These measures by the end of January 1915 brought the number of anti-balloon guns available up to a total of 97, of which 74, usually committed by platoons, were on line at the front, while the majority of the remainder were committed to defend airplane hangars.

In the meanwhile, however, aircraft had been armed and now used machine guns as well as small bombs in attacking troops as well as other targets, such as rail depots, supply and ammunition dumps, and rail transports. This compelled the General Staff in early 1915 to demand more effective guns for antiaircraft fire. The General Staff suggested to the manufacturing firms that they should use guns with a caliber of between 80 and 100 mm and a higher muzzle velocity for the purpose.

As previously stated, orders had been placed in August 1914 for 77-mm Model L/27 anti-balloon guns, mounted on motor vehicles and from XXXXXX August 1915 on the monthly output of these

17-18 guns was to reach the figure of 10 (Photo 14). Until then further emergency solutions had to be sought.

Troop units at the front used the 100-mm Model K.04 and K.14 guns of the foot artillery in addition to the Model F.K. 96 (Close Range) gun, hoping for greater effectiveness because of the larger caliber, hopes which naturally materialized. However, the Army lacked adequate numbers of such guns for use in ground combat, so that only very few of them were put to use for anti-aircraft fire. These guns also had an elevation movement of only 45°, for which reason they also were mounted on pedestals, which improved the elevation movement to 60°. They had a muzzle velocity of 590 meter/second and also a considerably longer range, firing to an altitude of roughly 6,300 yards (Photo 15). A special attachment was also mounted on these guns and improved firing performances against airborne targets.

Even the old models of fortress guns of the foot artillery were pressed into service dor air defense. Guns of the old 90-mm Model F.K.C. 73, still without barrel-recoil, and also of the 90-mm F.K. 73/91 Model were used on extemporized mounts. These guns still used bag cartridge shells ignited by a threaded percussion primer. With a well integrated gun team, their rate of fire was at the best three to four rounds per minute, and their muzzle velocity ~~of~~ was 464 meter/second. They were naturally not suitable for use at the front, but because of the lack of better

18-19 weapons, they were used in the rear areas to protect important military installations, where they proved fairly effective. Use had to be made of these guns right up to the end of the war, when they were still in service within the German interior for antiaircraft barrage fire (Photos 16 and 17).

Because front line officers were not always capable of finding emergency solutions for the use of Model F.K. 96 (Close Range) guns for air defense purposes, and also to secure at least some measure of uniformity, equipment manufactured in the zone of interior was supplied to the front line units. The materiel thus delivered included the "Koebe" guncarriage (Photos 18 and 19), of which approximately thirty were delivered, the "Schnetzler" gun pedestal mount (Photo 20), and several others such as the "Plett," "Wolgemuth," "Schaffhausen," and "Metz" constructions. Some of these were also used with the old 90-mm Model F.K. 73 and F.K. 73/91 guns taken into service.

The Rheinmetall Works also produced a 50-mm battery in October 1915, the guns of which had a muzzle velocity of 650 meter/second, an elevation movement of from -8° to $+50^{\circ}$, and a range of approximately 5,800 yards. These guns proved unsuitable, however, and the shells were not effective enough, for which reason they were not placed in production (Photo 21). However, the one battery produced remained in service for antiaircraft barrage fire at the coast, where the guns were in permanent emplacements up to the end of the war. This also serves to show that there

19 was a constant lack of adequate numbers of guns for air defense, so that every gun available had to be used to the utmost.

By mid-April 1915the number of anti-balloon guns on line at the front increased to 157, the number in the zone of interior to 41.

Owing to the mounting importance of antiaircraft action, the inadequate training, particularly of gunners, made itself increasingly felt. What was lacking was good and thorough peacetime training. To remedy this situation service or arms chiefs were appointed, with the mission of promoting training standards. The officers in these post had the concurrent mission of advising higher level headquarters, which showed little sympathy and understanding for the newly developing arm. In May 1915 a special firing range was established at Ostende at which officers and troops of the anti-balloon arm received training.

By the end of July 1915 there were already 420 anti-balloon guns in service. Of this number, the following were emergency solutions devised by the troop units themselves:

over 250 Model F.K.96 (Close Range) guns
60 90-mm Fortress Type K-C. 73 and 73/91 guns
15 100-mm K.04 and K.14 guns.

Special measures now had to be introduced to provide training in the use of rangefinders, since this was the instrument furnishing the basic firing data. A special school for the purpose was established at Ghent

19-20 The first captured guns adapted for anti-balloon fire xxxx reached the units on line at the front already in early 1915. Krupp, for example, had rebored the French 75-mm Model F.K. L/36 to use the German field artillery ammunition, thus producing the 77-mm L/35 anti-balloon gun (Photos 22 and 23). Separation of the lower from the upper gun carriage made it possible by means of lowering or raising action to achieve an elevation movement of from -7° to +70°, which was increased to +80° by the pedestals constructed by the troops themselves. Thisgreatly decreased the dead space immediately overhead. The muzzle velocity was 487 meter/second and a special attachment from the outset provided for a target altitude of 6.600 feet. The rate of fire was between 10 and 15 rounds per minute Later, when the original French barrels were too badly worn, these guns were given an inner lining of German manufacture, which slightly increased their muzzle velocity to 510 meter/second.

By the beginning of 1916 practically all French 75-mm field guns captured during the German advance into France had in this way been put to use as anti-balloon guns. These guns served as one of the main air defense weapons of the German Army xxxx throughout the war, from 1914-1918, and up to the end of the war approximately 400 of tjem were in service at the front.

20-21 The Model 00 and 02 field guns captured from the Russians were also converted for use as anti-balloon weapons. The caliber of 76.2-mm had to be retained, since it was not possible to rebore them to a caliber of 77-mm. It had been found that the use of these guns had rendered the tubing too brittle for reboring and the caliber difference was too small to allow the xxx removal of sufficient surface, so that the new tube surface would not havee been completely smooth. Retention of the Russian caliber of 76.2-mm created the necessity, however, to manufacture special ammunition for these guns after captured Russian stocks had been used. From September 1915 to June 1916 the firm of Rheinmetall delivered these guns, appropriatel reconstructed, to units in the field. In the changed construction the guns were placed on pivot mounts, which gave them a traverse of 360°. They had a muzzle velocity of 588 meter/second, an elevation movement of -3° to +70°, and a maximum firing altitude of roughly 18,000 feet. The original plan was to use them in permanent emplacements, but some of them were also mounted on four-wheel wagons manufactured by the same firm. Six of these guns were also used as railway guns in August 1917, organized in two batteries of each three guns (Photos 24 and 25).

The 77-mm L/27 guns on motor vehicles, for which orders had been placed at the beginning of the war, also reached

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21-22 units in the field during the year 1915-1916.

The increasing frequency of enemy air attacks against German artillery observation balloons, and the enemy use of infantry attack and battle air units which participated in action on the ground by low level attacks, created the necessity for small-caliber weapons of air defense. The slow traverse movement of large-caliber guns and their conditions for range finding and aiming precluded their use for defense against low-flying aircraft. For lack of anything better, use was first made of the naval 37-mm machine gun. The barrel was placed on a wheeled mount or on some other mobile mount. The technical data of this weapon are as follows:

Muzzle velocity	540 meter/second
Elevation movement	-3^{0} to $+80^{0}$
Rate of fire	250round per minute
Ammunition	Shell with tracer

Effective altitude of fire about 8,300 feet.

Units on line at the front received their first deliveries of these weapons also towards the end of 1915.

The multiplicity of gun types in service complicated training activities and in particular the compilation of uniform service regulations. The reserve officers assigned to the anti-baloon arm naturally also included technically gifted personnel who competed with the small number of regular officer in efforts to improve the performances of their service.

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22-23 However, it was left largely to the initiative of each and every individual officer to find means commensurate with his inventive ability to improve the performances of his unit.

2. Reestablishment of the Artillery Proving Commission and Its Participation in Development of the Antiaircraft Arm; 1916-1918. After deactivation of the Artillery Proving Commission and the other technical agencies of the Army at the beginning of the war in 1914, the necessity was realized in February 1916 to reestablish these agencies.

For this purposes former officer staff members of the old Artillery Proving Commission who were still available were recalled from their current posts . A vast volume of material had accumulated and had to be screened and processed. Suggestions from the troops or from other qualified and unqualified sources had to be checked for further examination or rejection. Besides many good and practicable suggestions there were also there were also suggestions from inventors totally ignorant of the subjects concerned. In many cases it was obvious that the sole intention of the author was to have himself declared indispensable and thus escape conscription for military service

It was also necessary to discuss and examine with industrialists new designs of equipment of all types. The small cadre of officers available from the former Artillery Proving Commission was naturally totally inadequate for these purposes, 23-24 The number of officers from the former Military Technical Academy was also far too small, so that it became necessary to use troop officers completely lacking technological training of any king. Officers of the reserve were also recalled to fill the gaps.

Unfortunately, it soon became evident that neither the Personnel Officenor the units in the field were willing to make the necessary sacrifices and special measures had to be taken to secure suitable personnel for the responsibilities involved. The natural desire was to secure primarily regular officers, since it was hoped that these would remain available after they had been educated and trained for their technical tasks.

In order to familiarize industry with the requirements of the new antiaircraft arm under front line conditions, engineer personnel from the industrial firms were taken on tours of the front, in each case under an officer, at the end of 1916. The industrial engineers participating in these tours were principally from the optical and gun manufacturing branches. In many cases they had opportunity to observe the batteries in action while themselves in the battery positions and could then discuss with the battery officers personally their needs and difficulties According to the abilities of the escorting officers, these tours produced results of varying success.

However, the tours were not only importantly instructive

24-25 for the industrial engineers participating in them, but also for the escorting officers, since the xxxxxxxxxx animated discussion of things personally experienced can produce very fertile results. Mutual visits to the troops of this kind should be a more frequent occurrence during which active discussions between the officers and engineers involved should be encouraged since this is the best way to show industry what is needed, and s nce such discussions are also very instructive for the officers concerned.

Only one example will be offered here to illustrate how urgently necessary it was for the Artillery Proving Commission to resume its activities:

Soon after the outbreak of hostilities came the complaint from the front that the enemy artillery was superior to the German, since it had a greater effective range of fire. This was particularly so in the case of the German F.K. 96 (Close Range) field gun which, because of its box-tail gun carriage, could only fire aith a barrel elevation of 18° and accordingly had a sighting attachment for an angle of only 18° equalling a range of 6,600 yards. By digging the gun-carriage tail into the ground, however, it was possible to obtain a higher angle and a correspondingly greater range, and for this purpose the War Ministry now instructed the appropriate firms to provide

24-25 the necessary ballistical data. Using the ballistic or range tables thereupon furnished by the firms, it was then possible with a muzzle elevation of 40° to achieve a maximum firing range of approximately 9,200 yards, which proved that the German guns were not inferior to the French in point of firing range. Following this the Artillery Proving Commission by means of photogrammetric recordings compiled ballistic tables for antiaircraft fire with the 77-mm L/27 guns, which corresponded to the barrel of the field gun Model F.K.96 (Close Range). These tables revealed that the guns had a maximum range of roughly 8,300 yards (7,700 meters), so that without knowing it all unobserved fire in the past with these guns at ranges beyond 6,600 yards had overshot the target. When this fact was proved beyond doubt and reported to the War Ministry, neither the Ministry nor the General Staff were prepared to pass the information on to the field forces, fearing that the information would destroy the confidence of the troops in their weapon. After a protracted struggle between the Artillery Proving Commission and the War Ministry, the Ministry was finally prevailed upon to prohibit unobserved fire with field gun Model F.K. 96 (Close Range) at ranges beyond 6,600 yards because of too wide dispersion of fire at long ranges. This at least prevented a senseless waste of ammunition in fire which could not produce possibly produce the desired results. It was only after

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25-26 the end of World War I, in 1919, that the ballistic tables for these guns were corrected.

For the handling of antiaircraft artillery matters the Artillery Proving Commission created a special sub-section under a Captain Aderholt. This sub-section was responsible for the development of guns and other equipment as well as for ammunition, insofar as the ammunition was subject to special requirements. In particular this applied to the testing of fuzes before their supply to units in the field was authorized. The subject of ballistics was handled in a sub-section for artillery ballistics, at the time under a Captain Becker.

It was in the year 1916 that a c isis commenced to develop in the field over the question of observed or unobserved (indirektes oder direktes Schiessen) fire by the antiaircraft artillery. Without cooperations from the Artillery Proving Commission and its scientific data, this problem definitely could not have been solved within the relatively short time in which it was actually clarified. In this way the Commission contributed very largely towards the good results achieved by the antiaircraft artillery in the war years 1916-1918, a fact which will evolve more clearly in the following chapters of this study.

At approximately the same time as the reestablishment of the Artillery Proving Commission in 1916, the Weapons and

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Ammunition Procurement Office was established under military control. It had been found that these matters could not be left for handling by the industry without thorough preplanning and a firm control. Bottlenecks in the supply of raw materials were so serious that compromise solutions had to be adopted continuously, many of which had perforce also to be changed again within a very short while. Steps had to be taken to insure the timeous supply of essential military equipment and materiel, with ammunition playing a particularly important role. It was essential to bring about a timely coordination between the military branches in order to meet the requirements of all in the execution of their several missions.

These tasks and the exercise of supervision and the work of acceptance, besides the financial accountings involved, called for the establishment of an appropriate new office. The Weapons and Ammunition Procurement Office thus established continued in existence until well after the end of World War I and took until well into 1921 to wind up its affairs.

3. The Anti-Aircraft Army in the War Years of 1916-1919.

The year 1916 brought significant changes in the German anti-aircraft artillery. First, there was the final consolidation of allantiaircraft artillery units under one service chief, a post filled by Major Grimme who had served previously as an instructor at Jueterbog.

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27-28 The title of the new service chief was Inspector of the Antiaircraft Artillery Arm.

In Spetember 1916 the German Army High Command (Hindenburg and Ludendorff) called for

(1) a numerical expansion of the antiaircraft artillery arm and improvement of its technical capabilities;

(2) Assignment of all antiaircraft artillery units directly under the several field army headquarters as army headquarters units and thus the withdrawal of these antiaircraft artillery units from the field artillery regiments assigned under the various divisions.

On 8 October 1916 the post of a Commanding General, Air (Kogenluft) was created, meeting the requirements of the Army High Command, as stated above.

Optical Equipment. A new problem of a technical nature in artillery fire developed towards the end of 1915 and the begining of 1916 and gained steadily in prominence. Many officers, the majority of them in non-regular status, occupied themselves with the problem of better firing results, basing their work on the technical experience gaind in their civilian professions Instruments of the most varied types were developed, designed to predict and fix the point at which target and missile would meet. The question of observed fire was also introduced into discussions by officers from the front. Serious resistance was offered to the introduction of observed or indirect fire by persons who refused to accept that a visible target could be combated more effectively by indirect than by direct fire. The instruments available for indirect fire control were admittedly extremely meagre, so that there was probably some justification for the negative attitude adopted by higher command levels. On the other hand, however, the increasing altitudes at which aircraft operated, initially around 4,000 feet but by now already around 10,000 feet, was beginning to complicate the sighting of aircraft and their identification as friendly or enemy units, and properly coordinated action by the sighting and firing gunners and the rangefinder operator was not always insured. Another difficulty was that of flagging the gunner at the tail of the gun carriage into alignment (in the case of guns not mounted on pivots) and the jerky way in which the muzzle followed the movements of the target. The introduction of indirect firing methods would have removed these difficulties and also would have made simplified sighting devices possible. All of these many problems required formulation and clarification in order not to leave everything to the initiative of the troops with the resultant development of different firing methods in every unit.

In all of these problems the cooperation of the reestablished Artillery Proving Commission was essential. To begin with, 26-27 the Commission by means of photogrammetric recordings precisely traced the trajectory of the shells. In addition trajectory divergence factors were determined in the case of the various guns as well as the influences of weather factors on the trajectory, wo that these factors could be taken into consideration. Another item of very especial importance was the determination of the fuze-burning rate at various altitudes, as this rate decreased considerably in regions with reduced air density. It was also possible to recognize a very wide dispersion of effect due to the irregularity of the fuzes, which showed clearly the necessity for an early departure from powder-burning to mechanical fuzes.

Initially, fire order charts had been issued for training purposes. These tables gave the lead factor for various altitudes at intervals of 550 yards, up to a maximum altitude of 2,500 meters; for various distances at intervals of 1,000 yards up to a maximum distance of 5,000 meters; for target speed at speeds of 10 - 20 - 30 and 40 meter/second. The tables were intended to give gunnery officers practice in formulating their firing commands in ~~xxxxxxxxx~~ uncontrolled firing. In the field under actual combat conditions it was naturally not possible to use these tables, since there was no time to refer to them; the gunnery officer had to acquire such a mastery of these factors that he could give his firing commands without any aids.

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29-30 As early as at the end of 1915 a lead computer designed by a reserve officer serving in an anti-balloon battery, an engineer by the name of Peres, had been tested in the field and then manufactured in large numbers and recommended to the individual platoons for use (Photo 26). In this system the lead rate in terms of the time of shell trajectory was measured by means of a scale engraved in the telescope. Only one-third of the time of shell trajectory was used in order to avoid too long a delay before actual fire, which would have enabled the target to change its course. These computations naturally caused an undesirable delay in the opening of fire for effect. It had been found, however, that the practice of estimating these factors merely on the basis of experience produced very unreliable results. Nevertheless, the troops complained about the time lag before they could open fire and initially rejected the use of these instruments. For this reason a special course of training was arranged for gunners at the battery position of Engineer Peres, where the personnel servicing the lead computer and the other members of gun crews could be given training in proper cooperation. The instruments were improved constantly and were further perfected by means of the newly established ballistic factors determined from the photogrammetric recordings of the Artillery Proving Commission. In this way Lead Computers A.M. 15, 16,

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30-31 and 17 were developed (photo 27), and already in 1916 a firing data disc (Photo 28) was supplied with the instrument from which the necessary factors for fuze timing and lead could be read off directly.

However, the instrument described above was designed for direct fire and its introduction created the necessity for an an additional gun-crew member, the lead computer, to properly sight the target before the necessary computations could be made and fire opened. In spite of this drawback it must be admitted that this was the first instrument which supplied properly computed firing data and thereby considerably improved firing results. Commensurate with the training of the gunner and his attitude towards the instrument its use was very valuable. At the end of 1916 practically all antiaircraft batteries were equipped with these instruments.

For indirect fire control, the adherents of which were becoming increasingly numerous at the fronts, an Antiaircraft fire data converter table, known as the Jakob Table, was compiled in 1917, which was also a result of the tours by engineers to the front in 1916 (Photo 29). Under this system, the target was sighted with the telescope and with the range data the current position of the target could be read of as the point of intersection with the altitude ruler. The target altitude was read off on the altitude gage of the rangefinder.

31-32 The point of target-missile impact was then computed on the basis of the lead factor. To find this point it was necessary to read off the factors for overall gun elevation and fuze setting. In this way the gunner was supplied only three factors: the lateral factor, the elevation factor and the fuze-timing factor, and there was no longer any need to take direct aim with the gun barrel at the target.

Also already in 1916, another reserve officer, an engineer named Schoenlein, had developed the "Schoenlein" lead data computer, which was not introduced for use, however, because it differed only inessentially from the Peres instrument. Instead it was redesigned for indirect fire control and finally in 1918 became the "Schoenlein" fire control director (Photo 30). Owing to difficulties with the industry, which was already working at full capacity on other projects, this instrument was not introduced for use by the field batteries when the war ended. Another instrument developed by Pschorr, also in 1916, was also not introduced for use, because it was so similar to the "Peres" instrument.

In March 1918 the War Ministry formulated the specifications for a future fire control director as follows:

1. The device must consist of the actual XXXXXXXXXX XXXXXXXXXX data computer and a fire control director. These will be separate instruments but so designed that they can

31-32 be readily combined.

2. The fire control director will be designed exclusively for indirect fire control.

3. Continual and progressive readings must be possible, creating the possibility for firing command at any desired moment.

4. Special speed gages will be combined with the ballistic data computer to insure uniform target data.

5. Weight, including mount and packing, not to exceed 110 pounds.

6. Personnel required to operate not to exceed 5.

7. The instrument must be a standard model for use with all types of guns, excluding small-caliber antiaircraft guns, and must be so designed that the special parts needed for adaptation to the various gun types can be readily exchanged.

8. Accuracy tolerance limits:

Adjusting elements plus/minus 2) at altitudes up
or lateral Side/parts plus/minus 5) to 3,300 yards

at altitudes from 3,300 to 6,600 yards plus/minus 55 yards

at altitudes above 6,600 yards plus/minus 110 yards.

9. Combination of the rangefinder and the ballistic data computer is not a specific requirement; but uniform target data computing must be insured.

10. Allowances must be made for changing target altitudes.

11. Data transmission from the directing instruments to the guns will be by means of

a. from central fire director by tracking indicator

b. by telephone

c. by voice.

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32-33 12. The firing data readings must be in simple, easily intelligible, and easily legible series of figures.

13. The firing data shown must be for elevation, basic angle, fuze timing.

14. Graduation: adapted to the graduations customary in the field and foot artillery forces.

15. Effectual range: Altitude up to 20,000 feet
XXXXXXX Distance up to 11,000 yards
Altitude angle up to +70°.

From these specifications it is obvious that those responsible clearly realized that antiaircraft artillery action was no longer possible without instruments of this type.

The result of what has been said was that by the end of the war in 1918 the equipment of practically every battery included the Peres lead computer and the Jakob data converter table. Priority was given to the Jakob converter table (for indirect fire control), and the Peres lead computer was only te be used by units not yet in possession of the converter table. Visual aiming, which had been the general practice until well into 1917 because of the lack of supporting instruments, was then generally rejected as unsatisfactory.

No such supporting instruments existed for small caliber (machinegun type) antiaircraft weapons, which had to rely on the ring and bead sight also used by normal machine guns.

The 18x inverted image rangefinder with its basis of 1.25

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33-34 meters was improved in 1915 by the addition of an altitude gauge. This gauge was mounted on the side of the range finder and by manipulating a pendulum on the one hand and setting the angle of the terrain to the target (sighting) the flight altitude could be read off from the altitude curves. Owing to the increasing target altitudes, the 1.25 meter base was no longer adequate, and in 1916 the rangefinders in use were replaced by a 2-meter inverted image rangefinder which furnished adequately reliable data up to a slant range of 20,000 feet. Later, from the end of 1917 on, 88-mm and 105-mm AA guns were furnished 4-meter inverted image rangefinders with a magnifying power of 20, which furnished considerably more accurate firing data. Starting in 1916, tests were conducted by the antiaircraft artillery with the naval panorama rangefinder. Many circles rejected its use because it called for special training and because it required the power of stereoscopic vision, of which not everyone is capable. However, it embodied important advantages, namely, in respect of the accuracy of the data procured, so that it was introduced, primarily for use in the 88-mm and 105-mm batteries. It was supplied with a 2-meter and with a 4-meter base. The 4-meter panorama rangefinder furnished very satisfactorily accurate data at slant ranges ~~altitudes~~ up to 33,000 feet.

Tests were also conducted with multi-fix (<u>mehrstationaer</u>) rangefinders. However, these proved fruitless and the

34-35 fact of these tests merits only this incidental mention here.

ANTIAIRCRAFT GUNS

In 1916 larger numbers of antiaircraft guns at last reached the front so that it was at last possible to discard the numerous expedients meanwhile adopted.

Krupp, for example, in 1916 delivered captured Russian guns converted as 76.2-mm antiaircraft guns on wheel guncarriages, in construction similar to the captured French guns converted as 77-mm Model L/35 antiaircraft guns. Deliveries commenced at the end of 1916. The technical data of these guns were as follows:

Muzzle velocity	590 meter/second
Rate of fire	10 rounds per minute
Maximum altitude of fire	18,500 feet
Movement of elevation	$+12^{\circ}$ to $+62^{\circ}$ or

when carriage tail was dug into the ground $+20^{\circ}$ to $+70^{\circ}$ (Photo 31).

Using captured Russian Model 02 76.2-mm guns, Krupp produced an wheel-mounted antiaircraft gun with an even better movement of elevation(Photo 32).

Using captured French 75-mm field guns unchanged, another effort was made to produce a pedestal-mounted antiaircraft gun for the infantry divisions (Photos 33 and 34). However, the new solution again proved unsatisfactory in point of mobility and speedy fire action, so that no more of these guns

35-36 were produced.

Furthermore, at the end of 1916 the first deliveries arrived of the guns newly developed in accordance with the specifications stated by the General Staff in 1915. By the end of 1916 the following guns from these deliveries were placed in service:

Krupp: : 2 80-mm motor-vehicle-mounted AA guns
" : 2 88-mm " " " " "
Rheinmetall: 2 88-mm " "" " " "
Krupp : 2 105-mm " " " " "
Rheinmetall: 2 105-mm " " " " "
" : 2 105-mm Railway AA guns.

These guns were developed in line with the latest experience available to the industry on the subject of antiaircraft fire action. They were all pedestal constructions which were to be mounted on motor vehicles.

The technical data of the various models were as follows:

Krupp: 80-mm motor-vehicle mounted gun--barrel length L/45
Velocity 715 meter/second
Maximum altitude of fire roughly 21,000 feet (6,450 meters)
Movement of elevation 0^{o} to $+70^{o}$

Krupp 88-mm motor-vehicle-mounted gun--barrel length L/45 (Photo 35)
Muzzle Velocity 705 meter/second
Maximum altitude of fire roughly 22,600 feet (6,850 meter)
Movement of elevation 0^{o} to $+70^{o}$.

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36-37 Rheinmetall: 88-mm motor-vehicle-mounted gun--barrel length L/45 (Photos 36 and 37)

Muzzle velocity	705 meter/second
Maximum altitude of fire	approximately 22,000 feet ((6,850 meters)
Movement in elevation	0° to +70°

Rheinmetall: 105-mm motor-vehicle mounted gun--barrel length L/35 (Photo 38)

Muzzle velocity	580 meter/second
Maximum altitude of fire	5,800 meters (approximately 19,000 feet)
Movement in elevation	-4° to +70°

Krupp : 105-mm motor-vehicle mounted gun--barrel length L/45

Muzzle velocity	720 meter/second
Maximum altitude of fire	7,350 meters (approximately 24,000 feet)

The firm of Rheinmetall also delivered the 105-mm piece as a railway gun. This was the first railway antiaircraft gun becoming available and it was demonstrated in August 1916 (Photo 39).

The 105-mm gun from Krupp proved too cumbersome for use in the front areas, and from then on Krupp delivered this piece for use in permanent emplacements (Photo 40).

By the end of 1917 the following numbers of these modern antiaircraft guns were in service

46 80-mm motor-vehicle mounted
52 88-mm " " "
6 105-mm as railway guns and in permanent emplacements.

37 By the end of the War the numbers of such guns in service totalled:

78 80-mm motor-vehicle mounted
160 88-mm " " "
6 105-mm Railway guns
38 105-mm in permanent emplacements.

Other antiaircraft guns also came into use in 1917-1918, which will be briefly mentioned here:

Using captured Russian 76.2-mm guns Krupp in 1917 constructed a pedestal-mounted antiaircraft gun in that year. The solution found was sound, and these guns rendered good service in spite of the loss of time in going into firing position because of the necessity to dismount the wheels and place the gun on 4 cantilevers on the ground. (Photos 41-and 42).

Sight must also not be lost of the fact that the firm of Henschel, which normally concentrated primarily on the manufacture of locomotives, also manufactured guns in 1918. This firm delivered a 76-mm motor-vehicle-mounted antiaircraft gun which was in service at the front, but the war was over before the firm could complete its 105-mm railway gun (Photo 43).

In spite of all the measures taken, however, the antiaircraft guns becoming available were still inadequate, and

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37-38 in 1918 captured Italian Model 06 and 11 field guns were therefore also converted to use as antiaircraft guns. From these models, Krupp produced a 75-mm antiaircrat barrage-fire gun, Model L/30 for use in permanent emplacements (Photo 44) This model had

a muzzle velocity of 510 meter/second and
a movement in elevation of +15° to +75°.

Aircraft speeds had meanwhile increased from 10 meter/ second, equal to roughly 36 miles per hour, to 50 meter/second or 108 miles per hour. Aircraft operating altitudes had also increased from a maximum of 6,600 feet at the beginning of the war to 16,500 and in some cases to 23,000 feet, the primary cause here probably being the need to escape fire from antiaircraft guns.

Since it was not possible in 1915 to make adequate numbers of the naval 37-mm machine guns available for antiaircraft defense, and since this gun proved only conditionally serviceable under front line conditions, Krupp in 1917 constructed a 37-mm pedestal-mounted antiaircraft machine gun (Photo 45), a weapon initially intended as armament for zeppelins. The technical data of this model were as follows:

Barrel length	L/14.5
Muzzle velocity	350 meter/second
Movement in elevation	-5° to +80°
Maximum altitude of fire	2,200 meters (approximately 7,200 feet)

Rate of fire	120 rounds per minute
Ammunition	solid projectile with tracer

In addition the 37-mm automatic gun, generally used in permanent type fortifications for raking fire was adapted for use as an antiaircraft gun (Photo 46). The technical data of this weapon were as follows:

Barrel length	L/32.2
Muzzle velocity	540 meter/second
Maximum firing altitude	2,500 meter (approximately 8,250 feet)
Movement in elevation	80°
Rate of fire	40 rounds per minute
Ammunition	solid projectile with tracer.

Finally, the fact merits mention here that at the end of 1917 a 20-mm ~~antiaircraft~~ cannon from the firm of Becker (Oerlikon) also came into use (Photo 47) as an antiaircraft gun. This weapon was on a pivot mount giving it a movement in elevation of -5° to $+80^{\circ}$, and had a bead and circle sight. It fired a solid tracer projectile with a muzzle velocity of 500 meter/second to a maximum altitude of 2,000 meters (approximately 6,600 feet). This weapons was originally constructed for horizontal fire, however, and loading stoppages and dud rounds were such a frequent occurrence that it was decided in 1918 to withdraw it from use in the front lines.

Whereas the problem of finding suitable large-caliber antiaircraft weapons had thus to some extent been clarified, 39-40 World War I came to an end in 1818 before suitable solutions could be found for small-caliber automatic antiaircraft weapons.

In August 1917 the Commanding General, Air Forces, formulated the following specifications for the development of small-caliber antiaircraft guns:

Minimum muzzle velocity 1000 meter/second
Type: Automatic Gun
Ammunition with faint tracer (to ignite after 550yards and continue burning to farthest antiaircraft firing range od 4,400 yards)

These specifications were not met by the end of the war. The following models were under development but work ceased at the end of the war:

Krupp	: 37-mm antiaircraft gun with separate line of sight
	37-mm " " with attached line of sight
Rheinmetall	: 50-mm " " with attached line of sight.

The plan had been to introduce electrical control mechanism designed by Lieutenant (Reserve) Schnetzler, but after tests these plans were dropped.

The plan existed prior to the end of World War I in 1918 to standardize the large variety of antiaircraft weapons, and the decision was taken to manufacture only one medium model in the future, namely, the 76.2-mm gun, motor-vehicle-carried. The 80-mm model was to be discontinued because its advantages

40-41 over the 76.2 model were not adequate to justify its continued production, while in the heavy weapons class ist mounting almost equalled that of the 88-mm gun, for which reason preference was given to the latter. The 105-mm gun (for permanent emplacement) was to be retained as a superh avy model.

All other antiaircraft guns were to go out of production.

AMMUNITION

It is necessary to establish from the outset that it was thought initially that the ammunition in use by the field artillery would prove suitable for fire action against airships and airplanes. It was even expected that the air pressure from the shell burst would prove very effective. At the start use was made primarily of shrapnell shells against airborne targets, but it soon became evident that the shrapnell charge rarely reached its target during the targets departure. Furthermore, the effectiveness of shrapnell shells declined seriously when stell shot came into use as the shrapnell filling because lead was in such short supply. The manufacture of shrapnell shells was also a far more complicated process than that of normal e plosive shells, and since the AAA arm was the largest single user of artillery ammunition, this factor also played a role in the decision to change over to explosive shells. It was expected that the blast of the exploding shell would be effective within a radius of 330 yards. These hopes were grossly

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41 exaggerated, although it is a fact that inexperienced airmen actually did receive a severe shock on many occasions when suddenly taken under fire, particularly by the heavier guns with a caliber of 105-mm. From the spring of 1915 on shrapnell was no longer used against airborne targets.

The double-action time and percussion fuze taken over from the field artillery proved by no means suitable. Whenever fire was directed at targets in the higher strata of the atmosphere there were alarge number of failures because the fuze was extinguished. Furthermore, with the increasing altitudes at which enemy aircraft operated the burning time of the fuze soon proved inadequate. Efforts to remedy these flaws by modifying the position and form of the fuze opening and by using a slower burning fuze ring failed to produce satisfactory results. The effect was found to be even more widely dispersed than before, so that it was found necessary after short teste to discard the slow-burning fuze ring in order not to reduce considerably the performances of the antiaircraft artillery.

In order to avoide damage by xxmbx shells striking the ground after their time fuze had failed, the percussion fuze was deactivated, and in newly manufactured ammunition for the antiaircraft artillery no percussion fuze was built in. The powder-train time fuze was very sensitive to atmospheric moisture and weather conditions, although every delivery accepted

41-42 was carefully checked by the Artillery Proving Commission, which earmarked any shipment showing a large percentage of failures for Army purposes, so that only especially good shipments came into use against airborne targets. In spite of this, numerous complaints were still received from units in the field, for which reason antiaircraft artillery authorities pressed with steadily increasing urgency for the mechanical time fuzes which had long been in the process of development. However, it was 1917 before a slow start was made at converting to these new fuzes, and even then only for the 88-mm and 105-mm ammunition.

The firm of Krupp-Tiel had developed a mechanical fuze on the clockwork principle, the firm of Junghans one based on the principles of centrifugal force and the revolutions of the missile in flight. Both of these were a marked step forwards but the war was over before they could really prove effective.

All efforts to improve the effectiveness of shells failed. Innumerable suggestions from inventors dealt in particular with this subject, but all proved fruitless. Shells were tested with fillings of chain, wire netting, or small explosive missiles, XXXXXXXXXXXX incendiary agents, and so forth. The incendiary effect was naturally considerable in use against balloons and airships, but in other respects the results achieved were by no means spectacular, so that the added disadvantage of

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42-43 more complicated manufacturing processes sufficed for the rejection of all these solutions to the problem.

A serious source of concern was the shortage of copper, which created the necessity to manufacture the rotating bands of the projectiles from some other material. Tests were carried out with rotating bands made of zinc, aluminium, brass, cardboard and iron. In test by the Artillery Proving Commission the rings made of zinc and electrolytic iron gave the best results, but the resultant increased barrel attrition made the use of these metals impossible for the antiaircraft artillery with its guns of high muzzle velocity and rapid rates of fire. One method which helped to economize in copper was the use of reinforced copper rings, made by welding a copper coating to the iron. In this process, the part fitting into the ring grooves was iron, while that part of the band coming into contact with the smooth surface of the gun barrel was of copper. This reduced the copper needed by about 40 percent. Shells with these rings were supplied primarily to the antiaircraft artillery.

For the same reasons as those given above, a substitute material was sought for the manufacture of the shell cases. Brass supplies were depleted, and all measures taken to return empty shell cases from the front failed to make up the shortage. The Artillery Proving Commission tested shell cases made of

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43-44 iron, which were then introduced for general use. However, it was found that these could not be used to any large extent in the antiaircraft artillery, since they caused frequent loading failures because they did not have sufficient back impetus after the shell was fired. Failures of this kind could not be tolerated in the antiaircraft artillery, since its units had to deliver very heavy concentrations of fire within very short intervals.

Serious shortages in the raw materials used in the manufacture of gunpowder also made themselves seriously felt, and ammonal was used to extend the available supplies. However, the resultant powder was xetremely fine-grained (mikroskopisch) and absorbed more moisture than the normal powder charges, which caused seriously fluctuating muzzle velocities. This disadvantage was particularly serious in the antiaircraft artillery and restricted the possibilities of using this powder for air defense. For this reason, shells with a reduced propellant charge were used for antiaircraft barrage fire. This ammunition was designated as barrage fire ammunition and was used for unaimed fire at night or against airborne targets flying above a cloud cover. In such case the guns fired into an area w ich it was assumed the aircraft would pass through. The use of this reduced-charge ammunition reduced gun tube at-

44-45 attrition, a highly important factor in barrage fire, since such fire had to be maintained for a considerable time to insure that the area through which the aircraft were expected to fly would be covered when they did so. In using these shells the known disadvantages of reduced muzzle velocity and effective range as well as longer time of trajectory flight were accepted as inescapable. Special ballistic tables naturally had to be compiled making due allowances for all these circumstances.

The changes in gun performances due to the above circumstances were as follows:

76.2-mm AA gun: Muzzle velocity: reduced from 590 meter/second to 410 meter/second

Altitude of fire: reduced from 5,600 meter to 4,000 meter (approximately 18,500 to 13,200 feet).

88-mm AA gun : Muzzle velocity:reduced from 785 meter/second to 542 meter/second.

Altitude of fire: reduced from 8,200 to 7,300 meters (approximately from 27,000 to 24,000 feet).

Rheinmetall 105-mm AA gun: Muzzle velocity:reduced from 580 meter/second to 460 meter/second

Altitude of fire: reduced from 8,900 to 5,300 meters (approximately 29,500 to 17600 feet)

Krupp 105-mm AA gun: Muzzle velocity: reduced from 720 meter/second to 445 meter /second

Altitude of fire: reduced from 7,350 to 5,000 meters (approximately 24,250 feet to 16,500 feet).

45 SEARCHLIGHTS

The increasing frequency of night operations by airships and of air attack by enemy aircraft at night made the use of searchlights necessary. Initially, and up to 1915, the 60- and 90-centimeter searchlights available as fortifications equipment were used for the purpose. These models and the 110-centimeter model of the Navy, also taken into air defense use in 1916, were mounted on carriages giving them a movement in elevation of 90° and all-around traverse of 360°, and were thus converted as air defense or antiaircraft artillery searchlights (Photos 48 and 49). The inadequate beam range of these searchlights was improved by a stronger lamp (Beck Lamp) in the case of the 110-centimeter model and by the introduction in May 1918 of the 200-centimeter searchlight (Photos 50 and 51). The illuminating intensity of the models then in use was as follows:

110-centimeter searchlight--120 million Haefner candle power
200-centimeter " --440 million Haefner candle power

The illuminating ranges were:

60-centimeter searchlight--2,200 yards
110- " " --4,400 yards
200- " " --6,050 yards.

The number of searchlights in service in 1918 totalled:

70 60-centimeter searchlights
155 90- " "
465 110- " "
25 200- " "

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45-46 Mention must also be made here of experiments with two searchlights combined (Photo 52), the purpose of which was to increase the illuminating intensity. This combination was to be used because of the slow progress made in the production of larger models.

Tests were also carried out with 60-centimeter searchlights mounted together with machineguns or 20-mm AA guns, to expedite the opening of fire once the target was spotted by the searchlight (Photos 53 and 54). However, the dazzle effect of the searchlight showed that they had to be used separately from the guns.

Initially, each searchlight was assigned individually, but from mid-1917 on they were assigned by platoons and finally by 4-searchlight batteries.

Sonic detectors were introduced in efforts to spot the target the moment the searchlight was switched on. Just as the rangefinder equipment was designed to extend the range of human vision, the sonic detector was designed to extend the range of human hearing. Wit these instruments it is possible to detect sound direction ten times more clearly than is possible without hearing aids. Owing to the rate at which sound travels, the target at the moment of hearing is no longer at the point from which the detected sound emanated. This made it necessary to use time lag computers to determine the current distance

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46-47 of a target from the point at which the sound is detected, and it was 1917 before instruments of this type reached the front units. In spite of all their inherent weaknesses, these first sonic detectors served to improve the illuminating effect of the searchlights considerably. During the war of from 1914 to 1918 51 enemy aircraft were brought down by German units acting with searchlight support (Photos 55 and 56).

BALLOON BARRAGES

Besides the weapons discussed above, balloon barrages also came into use in 1917 in home air defense. According to current wind conditions, barrage cables were sent aloft by kites or balloons. The idea was that aircraft would collide with these cables when attacking the defended target. Such barrages could not extend to any great altitude, but they were nevertheless greatly feared by enemy airmen. They compelled attacking aircraft to operate at altitudes which considerably reduced the aiming accuracy with the facilities available at the time. When committed as a surprise measure barrages of this type proved highly effective. At the end of the war there were in existence eight balloon barrage battalions, some of them with as many as fifty balloons. They were committed to protect industrial installations in the Saar and Moselle valleys, in Luxemburg, and at Cologne-Leverkusen.

47-48

SUMMARY

What has been said in the foregoing chapters will serve to reveal how highly diversified the antiaircraft arm was, and the widely diverging types of equipment used for air defense purposes. Whereas the original German anti-balloon artillery at the beginning of the war in 1914 had a strength of only 14 guns, its gun strength by the end of the war in 1918 had increased to 2,576. Only a very small percentage of these could, however, be considered as fully effective equipment. The types in service were as follows:

370 guns (approximately) of 3 different types with a claiber of 37 millimeters

One experimental battery of
4 50-centimeter guns of one type

one experimental battery of
4 65-centimeter guns on motor vehicles , of one type

40 75-mm air barrage fire guns (in permanent emplacements) of one type.

600 76.2-mm AA guns of ten various types

150 77-mm " " Model L/27 of various types

460 77-mm L/35 guns of four different types

600 90-mm guns (from fortress stocks) of one single type

80 80-mm motor-vehicle-carried AA guns of one single type

160 88.mm " " " " " of three different types

50 105-mm AA guns of six different types.

During the whole war a total of 1,154 air attacks occurred against targets within Germany, as follows:

48-49 8 in 1914 against zeppelin hangars and targets in Cologne and Freiburg

37 in 1915, including 7 at night, against factories, other industrial installations and Karlsruhe

96 in 1916, including 75 night attacks

376 in 1917, including 130 night attacks

637 in 1918, including 234 night attacks

Although protection against air attack was required only for those areas which were within the striking range of enemy aircraft, and thus within a zone extending to 300 miles behind the front, the following guns had to be committed in home air defense:

1915	150 AA guns
1916	410 " "
1918	900 " " (approximately).

German antiaircraft artillery units shot down:

1914-15	52 airborne targets of all types
1916	323 " " " " "
1917	467 airplanes
1918	748 "

The average expenditure of ammunition per aircraft shot down was:

1914-15	11,585 rounds
1916	9,889 rounds
1917	7,418 rounds
1918	5,040 rounds.

From the above figures it is evident that the antiaircraft

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49 arm was improving and that its performances were mounting steadily. In addition to better weapons, this was due to improved training. The antiaircraft arm had become a serious hazard for enemy airmen.

The ratio of enemy aircraft downed by German airmen to those downed by antiaircraft fire was 4:1.

Besides its action against airborne targets, the antiaircraft artillery had also proved its worth in action against ground targets. It effectively supported the infantry, particularly in the spring offensive of 1918, and contributed largely towards the successes achieved. Already in the first large-scale tank battle at Cambrai in October 1917, antiaircraft units employed as antitank artillery had given an excellent account of themselves. In this type of action they had become the backbone of the Army and had become an indispensable component.

The antiaircraft units employed against tanks, destroyed a total of 52 tanks, a highly meritorious achievement for the new arm of those days, w ich was neither intended nor trained for such combat action.

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CHAPTER THREE

THE GERMAN ANTIAIRCRAFT ARTILLERY AND ITS DEVELOPMENT BETWEEN WORLD WARS I and II (1914-1918 and 1939-1945)

1. The Peace Treaty of Versailles. After the end of World War I in 1918, the German Army was prohibited in terms of the Treaty of Versailles from retaining its antiaircraft artillery arm. Only the Navy was permitted within very narrow limits to have antiaircraft guns for the protection of ships. As an exception, permission was granted to mount a very small number of antiaircraft guns, in permanent emplacements, within the fortress of Koenigsberg, Eastern Prussia, for local defense.

After lengthy negotiations, the Reichswehr [Germany's post-World War I 100,000-man Army] was authorized to have one motorized battery in each of the seven regiments it was allowed to maintain. This at least made it possible to use 76.2-mm and 77-mm AA guns from Krupp and Rheinmetall for these batteries. So far as any possibility of their being used for air defense purposes was concerned, however, the "wings of these batteries were clipped" in the strictest sense of the word. The graduated arc, which permitted a movement in elevation of 70° had to be removed and scrapped, and replaced by a graduated arc giving a movement in elevation of approximately 35°.

50-51 All other items of equipment for antiaircraft fire were taken from the batteries, including their rangefinders. All of these instruments had to be delivered to Inter-Allied Commissions or destroyed under their supervision.

To replace the dismantled weapons, the German Army was allowed to acquire the following pieces:

every five years 1 105-mm AA gun and
1 76.2 or 77-mm motor-vehicle carried gun

every two years 1 88-mm AA gun.

It was clearly evident to those imposing these conditions that the production of these weapons at this rate would be so unprofitable that any possibility of such production was practically excluded.

Furthermore, all development work for the antiaircraft artillery was fundamentally prohibited.

This was the basis on which work had to continue from 1919 on.

2. <u>The Study of Antiaircraft Artillery Problems in the Several Military-Technical Offices</u> (<u>the Artillery Proving Commission, the Inspectorate for Weapons and Equipment, and the Weapons Proving Section in the Proving Branch of the Army Ordnance Office</u>) <u>in the 1918-1932 Period</u>. Since the maintenance of an antiaircraft artillery arm was prohibited in terms of

51-52 the Treaty of Versailles, and since the reduced size of the military establishment made it essential to reduce the staffs in all technical offices, these several offices and agencies were combined and consolidated in 1919 under the Inspectorate for Weapons and Equipment (Inspektion fuer Waffen und Geraet) This new office no longer contained a special sub-section for antiaircraft artillery problems.

PERSONNEL IN THE INSPECTORATE FOR WEAPONS AND EQUIPMENT

Initially, the old officers who had received training in the Military Technical Academy were available as advisers, or as section and sub-section chiefs, while the officers who had been assigned as assistants from field units remained in such posts. However, attention now had to be given to the problem of training replacements.

The Military Technical Academy had been deactivated at the beginning of World War I and in terms of the Treaty of Versailles its reestablishment was prohibited. Added to this was the fact that the qualifications of the officers who had received training at the Academy and who now had to be discharged from military service owing to the reduced size of the Army were not recognized. Universities and technical colleges were not even willing to give them any credit whatever for the time spent at the XXXXXXXX Academy and thus shorten their further studies.

52-53 For the above reasons and as a start, the officers who had served in the past as assistants were given advanced training in courses conducted by the former professors of the Military Technical Academy. However, the school education and military background of these officers differed so very widely that this scheme soon had to be abandoned and a new way sought to train a rising generation of personnel.

A Major Becker in particular concerned himself with this problem of future personnel. One suggestion was to create a Technical General StaffCorps, but this idea was opposed by both the General Staff and the Personnel Office. Since universities and other institutions refused to give time credit for the time spent in studies at the Military Technical Academy, the goal for the future was to give these personnel training at a university and thereby the status of fully qualified technologists. Officers willing to undergo such special training naturally had to be awarded a commensurate special status, similar to that of members of the General Staff Corps. Also, it would be necessary to make special arrangements for them ,since they would have to receive emoluments liberal enough to insure that, after completing their studies, they would not leave the military service and seek employment in private industry. Candidates for the new positions were therefore accepted on conditions under which they would remain in the service in Civil

53-54 Service status even if they should become physically unfit for military service. During their training at universities and technical colleges, and other such institutions, which lasted a number of years, these officers were naturally lost to the troops and the danger existed that they would become estranged. Finally in 1922, the first of these officers were detached for the purpose of study.

The selection of candidates for these special studies took place simultaneously with the selection of candidates for General Staff Corps Training. This selection was made at the Military or Corps Area Headquarters examinations, and normally, candidates were prepared for these examination in courses conducted with troops. This was not the case for the subjects of the military-technical examination, which from then on ~~xxxxx~~ took place simultaneously with the normal Military Area Headquarters examinations. Every officer was required to sit for the normal tactical examination, but could decide for himself whether he would sit for the military-technical examination or not. This in itself indicates that technology was considered less important than tactics: a candidate for technical training was required to also pass the tactical examinations for admission to General Staff Corps training, but not vice versa. The General Staff Corps candidate was not required to prove that he had at least a basic knowledge and understanding of the fundamental principles of

54 technology and could appreciate them and apply them usefully.

The struggle for full recognition of technological training and for a system of preferential promotion for these personnel, similar to the preferential promotion awarded to members of the General Staff Corps, was not yet won, and it was therefore only natural that a large majority of officers showed a marked preference for tactical subjects. For this reason numerous officers after passing the Military Area Headquarters examination chose the course of General Staff Corps training even if they were qualified for either of the two courses, a tendency which was strengthened by the fact that they were encouraged by the officers conducting the examination to do so.

This was not the only difficulty. It soon became evident that even those officers who had qualified in their technological studies in many cases were inclined to seek advancement in the General Staff Corps. In this way many particularly suitable officers for the technological career were lost to the technical services, a development which even received encouragement from the General Staff Corps and the Personnel Office.

In order to obtain fully qualified technological officers, it was decided finally to accept only candidates who had graduated after a full course of technological training at a university or similar educational institution for the technological careers in the Army, and it was even considered desirable

54-55 for them to hold a doctorate in technology. However, this would have required at least another year of study at a university or other institution, and this would have involved too great a risk that such officers would become estranged from the military service.

The German Navy accepted the idea of university studies, but did not insist on a graduate certificate, requiring only proof of a few semesters of study. The Air Force, when it was established later, adopted a completely different course, a subject which will be discussed later, since it was only after 1934 that the Air Force made provisions for technical training.

For regular officers to complete a full course of university studies naturally also has disadvantages. First of all, such officers during the studies are not available for field service; the danger exists that they will become estranged from military service and might become a problem later under field conditions. However, this applied equally to General Staff Corps members, who were therefore required to serve an assignment with troops while holding any position in the General Staff Corps. Unfortunately, this service with troops was not as a rule enforced in the case of officers with a thorough technological training, and in the case of General Staff Corps officers there was also a marked tendency to depart from this

55-56 principle, to which circumstance a number of failures in General Staff officers of later periods can be ascribed.

However, what applied to General Staff Corps officers applied equally in the case of technologically trained officers: if an officer serving in the Ordnance Office did not insist personally on an assignment with troops, he was retained in his current assignment and the Personnel Office did nothing in the matter. This usually had a harmful influence on his military career, and what was more important, it was harmful to the mission he was to perform, namely that of assessing field experience and interpreting it for industry. The real objective was that this type of service was to promote and influence the development of the various items of equipment.

The danger also existed that a particularly able and technically qualified officer would feel the urge to enter the field of constructional designing, which would render him unsuitable for a position in which he is to act as a neutral appraiser and examiner of the suggestions submitted by the appropriate industries. It is only natural that every inventor or designer will evaluate his work higher than that of his competitors. However, the mission of these officers, for which they had been prepared in their studies, was not that of themselves designing constructions; the training was

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56-57 designed to develop special qualities for the testing of industrial productions. Industry, and also the various institutions of the economy, employ specialists who constantly apply themselves to, work in, and live with the various branches of industry. It must be accepted as an acknowledged fact that these specialists will be better qualified in their individual subjects than a military officer, who lacks practical experience and constant activity in the specific field concerned. It would therefore be wrong to try to teach these experts what to do instead of exploiting their abilities to the full. The mission of the technologically trained military officer must remain one of making suggestions and assigning missions to industrial concerns on the basis of his field experience with troops. His training is to qualify him to discuss these problems with industrialists in their own terminology, and in consultation with them to establish the essential conditions of construction.

From around 1929 on the first officers who had completed their university studies were available for assignment in the military technical departments, after having first been reassigned for a 2-year period of service with troops. Unfortunately, the Personnel Office did not use proper judgment in assigning these officers. That Office considered an officer who had completed his studies simply as a technological

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56-57 officer, without regard for the subject in which he had graduated in his university studies. This contributed largely towards a faulty evaluation of university studies. Some of the officers were given assignments on the General Staff, where they were retained permanently; others proved failures in their assignments with troops and for this reason could not be accepted for assignment in the Ordnance Office.

The number of technologically trained officers was at all times too smal to fill all vacancies appropriately, so that it became necessary time and again to assign troop officers. Here, I myself am an example, having been assigned to a technical post from the troops, although in the antiaircraft in particular there were numerous officers, also in my age class, in regular status woul could have been assigned. Officers coming from the troops naturally had the advantage that they were completely impartial in their examination of facts, and that their technological aptitude enabled them to discuss matters with the appropriate experts. These officers received ever new impressions and suggestions in the field units, ideas which in numerous cases could be properly appraised and submitted to the industrial experts with fruitful results.

Besides personnel in officer status, civilians were also employed in Civil Service status. These were persons from the engineering professions from the technical offices of

57-58 establishments which had been closed, such as the Rifle Factory and Cannon Foundry at Spandau. Their primary mission was to support the officers in their duties and in particular to prepare plans for mass production. For this purpose they had to supervise the standardization of parts amd the preparation of blueprint series. It was also not easy to find younger personnel to take the place of these staff members when they left the service. The industries naturally could have released a sufficient number, but these would certainly not have been the best qualified personnel available, or they would have been too firmly bound to the industrial concerns from which they came and would have shown preferences for those firms. For this reason very young personnel were frequently engaged, who were given employment in the appropriate firms for a short while, where they could gain the necessary insight for their future duties. It will be necessary to return to this subject later and also to deal with the efforts of the tebhnological personnel to gain more independence of action and even to displace the regular officers.

A great help were the artificers who had received training in specialized schools and who proved excellent assistants, particularly in the field of ammunition. Frequent use was also made of armorer-artificer officers, who had received a thorough technical training and were employed primarily in the field

58-59 of ammunition.

THE ARMY ORDNANCE OFFICE

After the Weapons and Ammunition Office had wound up its affairs following the end of World War I and the necessity ~~ar~~ arose to adapt its activities to peacetime conditions, the problem arose of combining the development with the procurement sections. Some felt that the development sections should be placed under those handling procurement, others that procurement should be under development. It as generally realized quite clearly that the two departments should work hand in hand, and that very close contacts between them would prove beneficial. These deliberations led to the creation of the Army Ordnance Office in 1925, which was organized in a Procurement Office and a Weapons Proving Department.

COOPERATION BETWEEN INDUSTRY AND THE ARMY ORDNANCE OFFICE

The end of World War I produced new viewpoints and new problems for the technological departments. The Treaty of Versailles also imposed certain conditions on the German industries, which seriously interrupted their contacts with foreign countries in military matters. German industrial firms were permitted to manufacture only those items of equipment which the Western Allies approved. Krupp, for example, was allowed to manufacture only guns in the heavy artillery

59-60 class, with a caliber of not less than 100-mm, while the firm of Rheinmetall was authorized to manufacture only guns in the class of light artillery, up to and including 105-mm light howitzers. In terms of the Treaty it was also established how many guns could be manufactured as replacements for worn out pieces, and the numbers thus allowed were so small that it was completely unprofitable to undertake any such production unless it was absolutely essential to do so. Gun production thus came to an almost complete standstill, and only ammunition and the gun barrels as such remained in production.

The circumstances described above brought about a complete change in conditions. Whereas in former times the industrial firms designed, developed, and manufactured equipment on their own initiative or under foreign contracts and then offered their finished products to the German military establishment, the initiative was now with the military, who had to state requirements to the industry and then develop the required items in collaboration with the industrial firms. In order to retain in their services a cadre of expert personnel and keep them interested in military affairs, the bigger firms were willing to make certain sacrifices, but they were not willing and also not able to carry the burden alone. These firms therefore maintained designing offices which received designing contracts from the military-technical offices, for which payment was

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60-61 made to the firms involved. An obligation towards the firms existed under which they would receive a certain average of contracts, sufficient to keep the engineer personnel required for these purposes currently employed. This program naturally required careful thought, in order to provide work which would actually produce useful results. Another factor was that Parliament and the Government exercised a constant supervision and control to insure that the funds allocated were actually put to useful service.

From what has been said it will no doubt be clear enough that the field of activities of the Army Ordnance Office was one of great responsibility and importance.

MISSIONS OF THE WEAPONS PROVING DEPARTMENT

The most important tasks evolving after the end of World War I were connected primarily with the exploitation of the experience gained in that war and with scientific research and tests to substantiate the findings arrived at. During the war there had been no opportunity for a thorough examination of many problems or to try out solutions in actual actual tests; instead, such solutions simply had to be adopted on the strength of experience in the field, etc., without any proper substantiation of their true value.

New experience gained in the fields of substitutes for raw materials and the principles of mass production called

60-61 for exploitation, and it was in these fields in particular that cooperation between the procurement and weapons proving sections was of such eminent importance.

In addition to the General Staff and the War Ministry, which in the past had been almost the sole agencies stating missions for the military-technical departments, the procurement departments now also became mission assigners. Apart from this, the Weapons Proving Department itself had a full program of problems to be examined and clarified. By virtue of its mission of collaboration with the industries, one of its responsibilities was to take up and examine new inventions for later exploitation in the military interests.

For example: at the end of World War I in 1918 tests were in progress in the Kurische Nehrung region (in Eastern Prussia) at Rositten to establish precise data factors for the influences of weather conditions on the trajectory of missiles. The data factors available in the past had always been doubted by units in the field, and it is true that they had been computed from the results obtained in a small number of target firing practices with the guns firing in only one direction. These tests at Rositten, in which the guns used fired from four directions --with and against the wind and diagonally from right and left --were interrupted by Germany's collapse in November 1918. By that time, however, a large volume of highly valuable material

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61-62 had accumulated, which now could and had to be processed. The work thus done proved that the former "Special and Weather Influences Data Factor Tables (B.W.E.= Besondere und Witterungseinfluesse)required only inconsequential corrections. These tests and the subsequent research work produced results which also were of very especial value later for the antiaircraft artillery, since it was possible from them to obtain absolutely reliable data for trajectory adjustments under changing conditions of atmospheric pressure, atmospheric moisture, and wind

It was also of extreme importance to exploit the possibility existing immediately after the war,and before the scrapping of all meteriel had to be completed, to determine by means of firing tests what influence the delivery of barrage fire had on the firing range of guns and on barrel attrition. Complaint had been received time and again from units on line during the war that the German lines were endangered during German artillery barrage fire, and that as time passed the shell trajectory had become steadily shorter. As a remedy it had been ordered at the time that during increasing deliveries of artillery fire, meaning after barrage fire had been maintained for a certain time, the aim of the guns was to be raised slightly. This measure was introduced purely on the basis of empirical principles and without any substantiation of the reasons why its introduction was necessary. Since all material had to had to be demolished anyhow it was possible without special expenditure to carry out massed concentrations of artillery fire, using the materiel destined for demolition, and to study the problems involved. These tests showed that there was no justification whatever for the assertion that the shell trajectory of all guns became steadily shorter during barrage fire. In the case of the Model F.K. 96 (Short Range) field gun and in guns subjected to similar stresses during firing, it was found that the shell trajectory actually did shorten slowly during the initial stages of barrage fire. After this initial stage, however, it was found that the range returned to normal, in all ~~probably due prim~~probability due primarily to heating of of the barrel. On the whole it was established that there was no general shortage of range but a greatly increased dispersion of the fire. A result of this dispersion is naturally that when barrage fire is directed at enemy trenches very close to friendly trenches, the shorts included in the general dispersion will endanger friendly troops. In the case of guns with a caliber of 100-mm and more, barrage fire had the effect of reducing the muzzle velocity, so that the firing range actually did become shorter. Numerous tests carried out in efforts to find a remedy for this phenomenonfailed to produce a completely satisfactory solution. One experiment involved measurement of the explosion space in efforts to obtain a computing ~~factor~~

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63 formula for ascertaining the muzzle velocity reduction. This method was probably the best, but even it showed frequent sources of error. To compute velocity reduction on the basis of the number of rounds fired proved very unreliable, since it was a matter of decisive importance within what period of time the rounds were fired and what barrel temperature resulted. In the case of very rapid firing a few concentrations sometimes sufficed to render a barrel completely useless. In the case of slow firing, matters were completely different, and often hundreds of rounds could be fired without producing any changes. The reaction of the various barrels also differed individually. It was therefore found necessary to check current muzzle velocity frequently in order to determine the actual current capability of the barrel. These findings later proved of exceptional value to the antiaircraft artillery and their outcome was the stated requirement that muzzle velocity must be checked in the field. Antiaircraft guns in particular were required for lengthy rapid concentrations of fire and in the case of antiaircraft barrage fire for continuous very rapid fire.

Experiments were also carried out to determine the extent to which temperatures and powder dampness affected gun performances. When powder shipments were accepted, a prescribed quantity of the powder was required to show specific

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63-64 performances. If these performances were not achieved at the first test firing, the firm had the right to tender the powder a second time for acceptance. One device employed by the firms in such cases was to either dry out the powder or to add moisture, and frequently this resulted in the shipment being accepted when tendered for a second test. Since gunpowder has a strong tendency to absorb moisture, it was extremely important to determine the actual moisture content of the various types of powder under normal storage conditions.

It was found that storage near the coast already produced marked performance differences compared with powder stored in warm and dry areas. It is easy to conceive what results this can produce in the various theaters of war, in the East West, North and South. However, troops in the field have practically no possibility to determine the moisture content of their powder, and means therefore had to be sought of restricting the performance fluctuations of powder due to moisture absorption. Gelatinazation of the powder was found to be an excellent method.

Powder ~~XXXXXX~~ temperatures also play an important role in gun performances. In order to determine precisely the governing factors here, comprehensive series of tests had to be conducted for the various gun and powder types. On the basis of the findings made in these tests, the corresponding factors were entered in the ballistic tables and units were given instructions

64-65 concerning the proper storage of powder in firing positions, and other sites. It is common knowledge among members of the antiaircraft artillery how extremely important these factors are. The antiaircraft artillery in particular must give due consideration to all internal and external ballistic influences before opening fire, because it is of the utmost importance that the first rounds fired must hit the target.

A final solution now also had to be found to the fuze problem. The entire artillery, and not only the antiaircraft artillery, insisted on departure from the powder train fuze and introduction of the mechanical time fuze. The important point here was to formulate specifications according to which the appropriate industrial concerns could improve mechanical time fuzes , and have their designs ready for mass production when needed. The supplies of such fuzes in the late stages of World War I were from small-scale production without any final data.

During World War I the shortage of high-value chromium-nickel steel for the manufacture of gun barrels had made itself felt in a steadily increasing measure. The whole raw materials supply basis thus had to be reorganized. A very comprehensive gun-barrel proving program was carried out to test tubes of pure carbon steeland various other steel alloys. Particular importance had to be attached in these tests to the problem of barrel burst. The forging of a gun-barrel block, the fashioning

65-66 and finishing of the actual barrel from that block required large installations and wide experience. To avoid these expenditures tests were made by means of auto-frettage (super-pressure) the object being to shrink the metal and thereby achieve greater strength. It was also hoped that the same effects could be obtained by firing a few rounds of slightly oversize shells through the barrel. In this process the tube during the passage of the missile was to be strained to the limit of the metal's ductile strength. However, this method of cold frettage designed to give the metal added strength, did not produce the desired results and was not introduced.

Experiments were also essential to find a rotating band making it possible to dispense with copper, which was always in short supply. No other suitable material had been found during the war for this purpose. The most important point now was to maintain each gun barrel in usable condition as long as possible, and so the use of copper rotation bands was resumed immediately after the end of World War I. However, this was no solution for the future, and most unlikely that any such solution would be found in the future in foreign countries. The supply of raw materials was no serious problem outside of Germany, and foreign countries had not gained the experience we had gained in the years of 1914 to 1918.

It was 1937/38 before a suitable substitute was found

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66-67 in rotation bands made of sintered iron which made a departure from copper bands possible. For this reason the subject will be treated later in this study. It is necessary to point out here onwe again, however, how long reserach and development work of this kind sometimes takes, and that it is not possible when assigning a research and development project to stipulate a deadline for completion of the work. Practical work in such cases is preceded by basic materials research, after which come laboratory tests before trial products can be made and subjectet to tests with their numerous failures and slow progress to perfection. Once a satisfactory solution has been found, the manufacturing data has to be worked out, a matter of particular importance in the case of ammunition where the quantities to be produced are so great. In view of the quantities involved a decrease of only a few minutes in the manufacturing processes can have enormous results, a fact which must be taken into account already during the research and development stages.

Another problem requiring urgent attention was that of the influence of twist on tube attrition, shell burst in the barrel, and so forth. Diverging opinions as to xxxxxx the most favorable type of rifling, whether the rifling should be the same throughout or should be progressive, produced a subject of constant contention. This question had only a small influence on the manufacturing processes, since on the turning lathes

67-68 the dies can be set to cut any rifling. Matters of importance here were the tube-face pressure on the rotation band of the missile and bore erosion at the forcing cone of the barrel. The shape of the ~~rifling grooves and~~ cam groove (Fuehrungsnute) and that of the edge of land (Felder) also played an important role. According to the muzzle velocity required and the shape and weight of the missile to be fired, th type and intensity of the twist had to be recalculated. Tests showed that the continuous rifling was not so much less favorable than progressive rifling as was maintained by many, and that in the case of small performances it even had certain advantages.

The experience gained in research and testing showed that before designing a gun for manufacture it is first necessary to establish in actual firing tests what form and length of twist the barrel and the shell must have to achieve the stated performances. In the case of ~~[illegible]~~ long-shaped missiles the twist must be different from that required for shorter missiles. The construction of the rocker is also influenced by these factors, since it is this part which must absorb the face pressure.

The increased performances conditioned by the muzzle velocities required resulted in increased tube attrition, including erosion at the forcing cone of the barrel. In the past use had been made of a jacket tube in which the innertube was

67-68 drawn by a shrinking process. When the inner tube was badly worn, the entire barrel had to be returned to the manufacturing firm, where the inner tube was extracted and a new tube drawn into the jacket tube, again by a shrinking process. This was a time-consuming and costly process, and in the long run could not be tolerated in the case of high-performance barrels. It was essential to find other solutions. In the first place, it was usually not the entire barrel which was worn, but only the part at the forcing cone, at the beginning of the rifling grooves. Attempts were therefore first made to use inner tubes constructed in sections, so that only the section which had become useless could be exchanged. Even in the case of barrel bursts it was usually found that the breech and breechblock, which were particularly difficult to manufacture, did not require replacing. For this reason, the breech part was also separated from the rest of the jacket tube and replaced by a part which could be screwed off. This solution was finalized around 1930, when the newly designed tubes were also introduced.

The matter of dividing the liner tube into sections presented more serious problems, and the joining edges of the individual tube sections in particular presented difficulties. If at all possible, these parts were to be so constructed that they could be exchanged within the firing position. Very thin-walled liner tubes were made which could be driven into the

68-69 inner tube by hammer with a very little clearance. Since the liner tube alone could not withstand the stress of firing, it had to be brought into full face contact with and supported by the inner tube or jacket tube before being exposed to excessive strains and stresses. The manufacture of these tubes with such a small margin of tolerance, however, proved an exceptionally difficult matter. However, the stated requirement was that it must be possible to exchange the tube within the firing or battery position, and since this requirement was maintained, work on this problem continued, although a completely satisfactory solution was never found. Later, gun barrels were manufactured in complete sections, a front, middle, and back section, each being the complete section of jacket, inner, and liner tube combined. This construction was required particularly in the case of high-performance guns, since it was at least possible to replace the separate parts in workshops in the near front areas without the necessity of having to ship the entire barrel back to the factory for repair. Later in this study it will be seen, however, that gun barrels of this type did not represent an ideal solution in all cases, and that there were cases in which it could not be applied, as, for example, in the case of the Model 41 88-mm antiaircraft gun. For the centrifugal casting processes introduced later, this method of liner tube construction had advantages, since they were round and smooth, which are

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69-70 indispensable requirements in the centrifugal casting processes of manufacture. This subject will be dealt with later in this study.

During World War I the problem of barrel bursts had repeatedly given rise to the question of whether whether ammunition was really the sole cause, or whether there might also be other causes. Tube fouling due to residual powder, the loosening of rotation band parts, and so forth, were also considered as possible causes for shells bursting in the barrel. However, tests carried out with intentionally fouled tubes showed not a single case of barrel burst. Nevertheless, other known facts showed that the tubes required closer examination to determine their influence on firing results. Two firms had manufactured guns showing the same performances but differing widely in dispersion error and the question was: What was the cause? Barrel vibrations were measured and it was found, as a start, that the vibrations with a high muzzle velocity differed widely from those with a low muzzle velocity. It was also found that fastening the barrel with a clamp to a vibration bulge prevents free vibration. This method of fastening the barrel was thus the cause of fire dispersion in the gun from the one firm. At the same time an explanation was found for the higher incidence of barrel bursts with these guns at the point where they were clamped, since the clamps were fastened to the barrel by

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70-71 a shrinking process which affected the barrel. These findings resulted in the adoption of new barrel construction and later to the construction of gun barrels without clamps. The solution of these problems was of value not only to the conventional but also to the antiaircraft artillery.

During the period under discussion, comprehensive tests were also carried out with muzzle brakes. It was hoped that the use of these would not only make it possible to increase the firing range of existing guns but would also make considerably lighter construction possible in the future. Under peacetime conditions the introduction of muzzle brakes was prevented because the side and back flow of the escaping vapors hampered the gun crews, and it was only during World War II that they came into use to increase the performances of existing guns. It will be shown here how significant this innovation was for the antiair raft artillery.

During World War I buffer brakes had shown a high incidence of interferences and had even frequently resulted ~~tox~~ in excessive strains on the guncarriage, causing guncarriage fractures which rendered the gu inoperable. The cause was either a loss of brakefluid, resulting in too long a recoil which snapped the recoil piston, or, in the case of excessive temperatures, to expansion of the brakefluid, which made the brake too rigid and too strongly retarded the recoil. This

71-72 placed excessive strains on the guncarriage and resulted in breakage. Approximately 80 percent of all guncarriage losses during World War I were due to these causes.

These circumstances made it essential to carefully check the construction of buffer brakes. The solution to this problem was found in the addition of a compensating cylinder to receive brake fluid if pressure became excessive and from which brake fluid could come in the event of fliud loss. This new construction had very beneficial r sults.

The possibility was also studied of replacing the counterrecoil spring mechanism built into the buffer brakes by an air pressure counterrecoil mechanism. The manufacture of these springs had always been a serious problem since particularly high-quality material were needed for the purpose and also because the number of personnel qualified for the work was always inadequate. The outcome of these studies was that the air pressure counterrecoil was almost universally adopted. The different types of buffer brake are recognizable from the fact that guns with spring-type counterrecoil mechanisms have no structure on top of the barrel since the springs are around the brake in the rocker (Wiege) beneath the barrel. The air pressure counterrecoil is placed on top of the gun barrel, while the tubular brake is placed in the rocker beneath the barrel.

71-72 The situation in regard to equilibrators was very similar to that in the case of the tubular recoil and the air pressure counterrecoil. In altitude adjustments the equilibrator was to balance the weight of the barrel, so that the elevating mechanism would not have to carry the entire load. The force needed to adjust the barrel to high elevation was to be approximately equally to that required in lowering the gun barrel. This was the function of the equilibrator springs in the cylinder beneath, or in two cylinders placed one on either side of the barrel. Very specially high-quality materials and exceedingly careful manufacturing processes were required also in the manufacture of these springs. Here again an attempt was made to use air pressure equilibrators. However, the difficulties encountered were greater than those encountered with the air pressure counterrecoil, because heat factors had a far greater influence on the functioning of the elevation adjustment gears. For this reason the use of equilibrators using spring mechanisms had to be retained.

Experience with foreign guns had shown the advantages of split-trail gun mounts. Consequently their use with German guns was contemplated and tests had to be conducted. As so frequently happens, it was found that the troops rejected this innovation. One disadvantage was the added weight resulting from the use of two booms instead of one. However,

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72-73 the split-train guncarriage gave the gun an increased field of traverse--from 6° to 60° --, an advantage which could not be disregarded, so that it gained steadily in favor.

In civil engineering the practice of welding, even in the structure of large bridges, had gained ground steadily since 1925. In view of this experience, the replacement of rivetted construction by welded construction was also contemplated for guns in order to cut down some of the additional weight involved in the transition to the split-trail guncarriage. In the beginning the most important source of concern here was that there were no suitable methods in existence to check the quality of the welding work done. In the case of rivets it was possible by hammering to detect whether the work was properly done or not, but no such method was known to check weldings. Tests were carried out with X-Ray photos, but there was no experience data available on which to base an analysis of the results. For example, since Krupp was not allowed, in terms of the Versailles Treaty, to manufacture equipment for light artillery, the firm of Rheinmetall on one occasion manufactured guncarriages under contract for Krupp. Krupp refused to accepted the welded work, while Rheinmetall maintained that the construction was sound. Krupp was thereupon given the guncarriages for tensile stress testing and found that it was completely impossible to tear the booms

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73-74 apart.

These doubts about the possibility of checking the quality of welded work are probably the explanation for the slow progress made in introducing welded work for use in the Army. Setbacks occurred time and again in which apparently sound work failed and caused breakages.

In welding, a special welding wire is required for each type of metal used, and the heating of the material during the welding process also plays a significant role, and it was found time and again that the welded seam itself was sound but that the adjacent material had been damaged by overheating.

The principal advantages of ~~XXXXXXXXXXXXX~~ welding over rivetting were

welding involved less work. Whereas every rivet had to be rivetted individually, the whole job of welding a boom was completed in a fraction of the time;

repairs could be carried out far more speedily and simply with the use of welding techniques;

welding made it possible to reduce weights considerably.

In welding there were two ways of joining: the overlapping edges of the two metal sheets could be welded together, or the two parts could be joined edge to edge. Both methods were used later and came into increasing use in the 1930s. In the field units there was also a strong aversion ~~inxthe~~ among the older artificers and in the repair shops to the welding [illegible]

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74-75 artificers and in the repair shops to the welding method, and it was only after very detailed courses of instruction that the new method gained a firm footing there.

Experience during World War I ~~[illegible]~~ with captured enemy materiel had shown that Germany was the only country with guns with a caliber of 77-mm, while most foreign countries had 75-mm (France, Britain, Italy) or 76.2-mm (Russia) guns. This complicated the use of captured guns and their adaptation to German mass production of ammunition, for which reason adoption of the most commonly used 75-mm caliber for German use was take into consideration. For these reasons the old 77-mm guns allocated to the post-war army were converted to a caliber of 75-mm. This measure was timed to coincide with exhaustion of the old stocks of 77-mm and the delivery of new 75-mm ammunition, which explains why a number of years passed before this conversion was completed. A beginning was made in 1926 and the whole action only terminated in 1930. This applied also to the motor-vehicle carried batteries, and thus to the anti-aircraft guns in service during World War I.

As in the case of the manufacture of guns and ammunition, preparatory wrok was also done in these years in the fields of optical and searchlight technology, which later served to benefit the antiaircraft artillery arm.

Although it was not possible to do any work on

75 weapons designed specifically for antiaircraft defense, and although all work on military equipment of any type was seriously hampered by the requirements of the Western Allies, the above account shows clearly that the responsible technological offices had by no means neglected these matters. Asstudy of foreign reports, insofar as such reports became available, and the exploitation of foreign military-technical publications formed the foundations on which all work had to be founded. All of these problems were therefore constantly followed up, and the German industries were impelled to continued their work in these fields.

When in the 1920s the Navy gradually commenced constructing ships to replace those in service, and concommitantly of arming these new ships, a start was made here at paying particularly special attention to the problem of fire directing equipment. In connection with this program, Army and Navy agencies took up this problem in particular in cooperation. Use had been made of the 88-mm and 105-mm antiaircraft guns still in the fortress of Koenigsberg as early as in 1926 for the resumption of firing tests, and from 1928 on the motor-vehicle-carried batteries of the Reichwehr artillery regiments (the 9th Battery in each regiment) were also included in this program of firing tests. However, the equipment needed for antiaircraft fire could only be issued to them at the firing

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75-76 range and had to be turned in again before they returned to their garrisons.

At the firing range their guns were thus given elevating sectors for an elevation movement of 70° in place of their 35° sectors. For the execution of the firing tests, the batteries also received experimental equipment in the form of range-finders and fire director equipment. These first antiaircraft firing tests were thus imperfect in every respect, but they did at least serve as an initial step in giving the troops a practical insight into the necessity of weapons of this kind, and it is in this light that these firing tests should be viewed.

In realization of the fact that the Artillery Inspectorate could not continue to handle the problems of antiaircraft artillery as a secondary responsibility, a special "Training Staff" known as Asta 3 was formed within the Inspectorate on 1 February 1930, with the mission of handling and following up all ~~antiartillery~~ antiaircraft artillery problems.

In the Army Ordnance Office, in contrast, there was still no separate section for antiaircraft artillery matters. Instead the Sub-Section for Heavy Motorized Artillery was required to assume responsibility for the antiaircraft artillery as a concurrent mission. The decision was no doubt wise, in view of the fact that any future antiaircraft artiller would certainly be motorized, to assign the responsibility to this

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76-77 subsection, and not leaving it in the hands of the light artillery, namely in the Sub-Section for Field Artillery, as in the past. Another advantage was that the Chief of the Sub-Section for Heavy Artillery at the time was a Captain Mertitsch, who had commanded a ~~XXXXXX XXX~~ motor.vehicle battery in the past so that he could be considered as particularly well qualified to represent the interests of the new antiaircraft batteries.

Work in the field of optical instruments was handled as hitherto in Branch 8 (Weapons Proving).

Ballistics and Ammunition problems were handled by Branch 1, which dealt with these subjects for the entire artillery.

Mechanical weapons were a responsibility of the Infantry Branch (Branch 2), while the Engineer Branch (Branch 5) handled searchlight matters.

3. Antiaircraft Weapons Development in the 1918-1932 Period. As has been shown in the preceding chapters, no possibility existed at the end of World War I to continue research and development work in the field of antiaircraft artillery. On the other hand it has also been shown that the theoretical and scientific study of these problems had not been neglected at any stage, but had constantly been followed up.

In the 1920s, however, preparatory work for a future antiaircraft defense rearmament gradually gained impetus. It is necessary to mention here that it was possibly an advantage

77-78 that there was no old equipment in existence and that something really new had to be developed. Justification for the commencement of work in this field was found in those conditions of the Treaty of Versailles which permitted Germany to maintain antiaircraft artillery for defense purposes in the Fortress of Koenigstein. Publicity was avoided as far as possible, but this was difficult, particularly because the funds required for such work had to be requested and approved by Parliament.

ANTIAIRCRAFT GUNS

The Sub-Section for Heavy Artillery, under Captain Mer-Kitsch, first negotiated with the firms of Krupp and Rheinmetall concerning a new 75-mm model antiaircraft gun sith improved performances. It was evident that the old type of motor-vehicle-carried gun currently in use in the Reichswehr could no longer be considered as a modern antiaircraft gun, even if it were equipped with an elevating sector for a movement in elevation of 70°.

Whereas at the end of the war in 1918 it had only been necessary to provide against xixxxxfx bomber aircraft with a maximum speed of 90 miles and fighter aircraft with a maximum speed of 120 miles, the speed of bombers in 1928 had increased to 150 and that of fighters to 270 miles. Maximum operating altitudes had also increased from 10,000 feet fxxxbxx in 1918 to 16,500 feet in 1928 for bombers and from roughly 20,000

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78-79 feet in 1918 to 26,400 feet in 1928 for fighters. These factors had to be taken into account in gun performances and also in the matter of other air defense equipment.

The 75-mm antiaircraft gun developed under the contracts awarded in 1928 was tested by Weapons Testing Branch 4 in 1930-3 Exercises with troops at a maneuver field showed that the projected system of turning over (Umkippen) of the gun for transport and its erection for fire action not only took up much time but also created hazards for the gun crew. As a first solution the system adopted was similar to that in use in the mounted artillery at the beginning of the war in 1914, in which the horse-drawn guns were turned over while in transport. It was found, however, that the increased weight of guns made this method even more impracticable than it had even been. The ground had to be levelled before the gun could go into firing position, and this was an unacceptable circumstance. Krupp therefore received instructions to expedite development of a suitable mount. Speed was essential because plans provided for another series of tests with troops in the field in 1932, and it was not desirable to burdxn the troops with this hazardous solution. The outcome was the outrigger-type gun mount (Kreuzlafette), later an almost universal item of equipment in modern antiaircraft guns. Almost at the same time a similar solution had been found in foreign countries to the problem of

79-80 suitable mounts for antiaircraft artillery guns. This is an interesting point, since it was found frequently during development work that similar items were created at separate places without the designers knowing of each others work. Solutions of this kind are simply in the spirit of the times and are found simultaneously by agencies working in complete independence of each other.

The technical data of the new gun were as follows:

Caliber	75-mm
Barrel length	L/60
Altitude of fire	33,000 feet
Movement in elevation	-3° to $+85^{\circ}$
Mount	Outrigger type

Guns of the new model were delivered to the troops in 1932 and the first antiaircraft artillery battalion activated at Berlin/Lankwitz and designated for concealment purposes as a supply train battalion, was equipped with them. The 9th Battery, 1st Artillery Regiment, in Koenigsberg, also received these guns.

The caliber of 75-mm had to be adopted, because the Reichswehr was only authorized to have 75-mm and 105-mm guns and it would have been too much of a risk to adopt a different caliber for a new motorized antiaircraft gun. The 105-mm caliber was considered too heavy for the new experiments, and this left 75-mm as the only possible choice. This was also one of the factors contributing towards the decision already in 1928 to

88 commence work on the development of an improved 88-mm model, another contributing factor being the excellent experience with this caliber during World War I.

The effectiveness of the 88-mm shell was considered still adequate for modern conditions and it seemed that the terrain mobility of such a gun would remain unimpaired even when its performances were improved to meet the stated requirements. Production of the 75-mm guns, which were a more urgent requirement, delayed completion of the development work on the 88-mm model, the main consideration here being that the troops had to have a gun for training and exercising.

The need for a light antiaircraft weapon had been realized already before the end of World War I in 1918, but no solution to this problem had been found at the time. There was even no clarity on what requirements should be specified for a weapon of this type. Now, the need arose initially to furnish such weapons to the Navy, which needed them urgently for the armament of its new ships. The firm of Rheinmetall had developed a weapon of this class on its own initiative and manufactured it at Soloturn. It was a 20-mm automatic gun and the Navy gave it preference in firing tests over the Orlikon 20-mm antiaircraft model which had been widely introduced in foreign countries. Mounted on a tripod for naval purposes, this new gun provided the basis for development of the improved Model 30 20-mm antiaircraft

81-82 gun and from 1928 on was also used by the Army for firing tests. The Model 30 was introduced in 1931 and supplied to the first light antiaircraft artillery units activated.

This new 20-mm Model 30 Antiaircraft gun had a recoil loader with tumble lock, and was mounted on two-axle free-aiming swivel-mount carriage. The pedestal was on a splittrail base covered with a sheet metal platform. When driving the two sides were raised. To lower the gun into position the ~~[illegible]~~ undercarriage was wheeled out, the guncarriage was levelled, and the sides were lowered to a flat position. The gunner aimed with the aid of a shoulder frame giving side and altitude directions, as was the case in the Navy.

In spite of certain advantages, this new gun was not considered satisfactory because of its guncarriage and the method od transport. Its line of fire was too high, it was hard to conceal, and aiming ~~[illegible]~~ was difficult because of the cramped crouching posture of the gunner. A number of improvements were therefore introduced in the next few years. Its movement in elevation was from -15^{o} to $+85^{o}$, and its theoretical rate of fire 300 rounds perminute. In practice, however, it fired only 120 rounds per minute. Its effective range was 1,760 yards and it was equipped with a telescopic sight for use against ground targets and a linear sight for antiaircraft fire. A range finder with a base of one meter

81-82 supplied the data necessary for antiaircraft fire. No protective shield was provided.

These two models, the 75-mm L/60 antiaircraft gun and the Model 30 20-mm two-wheel-mounted antiaircraft gun were the first two weapons introduced since 1918. However, both of these weapons were only produced in small numbers and served only to give the troops their first training in antiaircraft action. However, they remained the standard weapon of the so-called supply train battalions and for the AA machine gun battalions.until 1932.

OPTICAL INSTRUMENTS

The testing of rangefinding equipment was resumed as early as in 1925. The firm of Carl Zeiss, Jena, was awarded development contracts through Weapons Proving Branch 9, at that time under a Dr. Lechner.

In 1926 work was also resumed on the development of fire directing equipment. Instruments in this category were constructed by the firm of Carl Zeiss, Jena, with important direct support from Counsellor (<u>Geheimrat</u>) Pschorr of the Charlottenburg Technical College, who had commanded an antiaircraft battery in the war of 1914-18 and already at that time had submitted recommendations on the problem of fire director ~~problems~~. The instruments developed

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82-83 were tested continuously by the Navy, with willing assistance from students of the Technical College.

The first fire control director was completed in 1927. Initially it was designated Fire Control Director Model P-27 (Kommandogeraet P 27) and was used by the troops in antiaircraft fire practise at Koenigsberg. Following the first field tests with live ammunition at Pillau in 1928 a contract was placed with the firm of Carl Zeis, Jena, for a first series of these instruments, ten in number, which were delivered in 1930-31.

The Navy did not adopt this instrument, since its personnel were accustomed to working on the angle velocity indicator principle and preferred instruments of that type. Working on the basis of the naval instruments, the Army later developed its auxiliary fire director (Kommando-Hilfsgeraet). The Pschorr type instrument used the course and speed of the target for data computing, and received these basic factors from a range-finder mounted separately next to it. The target speed was determined by a lead computor similar to the Peres lead computor used in 1917-18. These two data factors were fed to the fire control director instrument, which then calculated the point of target-missile impact and computed the fire data factors for traverse, XXXXXXXX elevation, and fuze setting for the guns.

83-84 An automatic fire control director was also designed in 1927/28 at the firm of Carl Zeiss, Jena, by Major Kerabetz, formerly of the Austrian Army. Thos model was designated "Tabulator" and the first such instrument was tested approximately in 1932. A second such instrument incorporating improvements based on these tests was constructed and tested in approximately 1934, but proved unsatisfactory and was not introduced for use.

In 1932 the Model P-27 Fire Control Director was thus available, from which departing point development work could continue.

In the field of searchlight development no important ~~work~~ preparatory work was done for a future antiaircraft artillery searchlight prior to 1932.

4. Development of the Antiaircraft Artillery in the 1932-1939. The training staff (Asta 3) established on 1 February 1930 in the Artillery Inspectorate (Inspectorate 4) within the Reich Defense Ministry used the experience of World War I and that gathered since then by the several technical departments for the compilation of a program to serve as a basis for the activation and equipment of the future antiaircraft artillery arm (Appendix 2). Main participants in this work were the later Inspector, Colonel Ruedel, and his Chief of Staff, Major Weise.

The principles thus established from then on for the time

84-85 being served as directives for the Weapons Proving Departments of the Army Ordnance Office.

The antiaircraft artillery program referred to above was issued in 1932 at the time when the first socalled supply-train unit (*Fahrabteilung*), actually an antiaircraft artillery unit, at Berlin/Lankwitz was being equipped with Model L/60 75-mm AA guns under direction by Major Weise. It was to serve in a certa certain sense as an experimental battalion to gather further experience in practice for the equipment of units and also for the further development of items of equipment.

In 1933 the 9th Motor-Vehicle-Carried Battery in each of the seven artillery regiments received personnel released from the supply train units, was reorganized as a mobile AA unit, and was equipped with antiaircraft guns. Another three such battalions were established in 1934, receiving cadre personnel from the existing battalions for the purpose. For security reasons these units were still designated "supply train battalion (*Fahrabteilungen*)" In 1935 personnel from the ten battalions thus in existence were used to activate another eight by this process there were 118 such units in existence in 1939.

At the end of World War I in 1918, the German antiaircraft artillery arm had had a total force of

2,576 heavy guns
625 heavy searchlights
70 light (60-cm) searchlights.

84-85 In comparison with these figures, there were in existence at the beginning of World War in 1939 the following German antiaircraft units:

650 heavy batteries with a total of 2,600 heavy AA guns
560 light " " " " " 6,700 light " "
188 ~~with 150 cm lamps and 60 cm lamps~~ searchlight batteries with a total of approximately 1,700 150-centimeter and approximately 1,300 60-centimeter searchlights.

The brief account given above reveals clearly what was needed and what was performed at the time under discussion here in this field. Great demands were made on the troops and on the ministerial departments, and those demands simply had to be met.

GUNS

The Model L/60 75-mm antiaircraft gun available in 1932 did not meet the performance standards required of a modern antiaircraft gun. The reasons why these guns were nevertheless manufactured have been related in the foregoing sections of this study. Meanwhile, however, preparatory work had commenced already in 1928 at the development of a new model 88-mm antitank gun, based on the 88-mm model used in World War I.

The new gun reached the troops in 1933, designated as the 88-mm Model 18 AA Gun. The designation digits "18" at the time were given to all newly adopted artillery items of equipment for security reasons and did not imply, as is quite commonly assumed, that they were identical with the items in use at

83-84 the end of World War I in 1918.

The barrel length of the newly introduced 88-mm AA gun, Model 18, was L-56. On the basis of former experience and the development research work done in the 1918-1932 period, it was divided into a jacket tube and a replacable inner tube. A screw-on breechblock held the bolt (Photo 57). The bolt was of the automatic and self triggering push-twist type which, after a round was fired automatically opened during the counterrecoil movement, ejected the used shell cartridge, and at the same time cocked the trigger spring. It was thus immediately ready to fire another round after the new shell was inserted. The bolt system was completely automatic. Muzzle velocity was 820 meter/second, and the movement in elevation was from -3° to $+85^{\circ}$.

Transmission of the fire data for lateral, elevation and fuze setting was by means of lamps with a following pointer,, so that used together with the fire control director instrument the data factors could be transmitted directly to the gun without word of mouth. The gun equipment also included a fuze-setting device, but it was mounted separately and therefore had to be hand serviced in accordance with the individual lateral data factors received. Loading could be done by a loading tray with rammer, but use was rarely made of this device, the crews usually preferring hand loading. Actually, a well

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86-87 trained and properly integrated crew achieved a higher rate of fire by hand loading. However this was not the only factor which had to be taken into consideration and in itself would not have been sufficient justification for hand loading. The need was not only to shorten the time requirements for data relay and loading but also, and this was even more important, to insure that the rate of fire could be sustained at a constant level, since the fire control director could then be set accordingly. During brief spells of firing practice, in which the number of rounds to be fired also had to be restricted, there were naturally no signs of exhaustion among the crew members hand loading their guns. The loading tray and rammer in use were easily subject to breakdowns, which was another reason why many gun crews preferred hand loading. Unfortunately, however, this meant that the defects could not be detected and remedied, a circumstance which had a harmful influence on the development of new gun models. In the case of heavier guns, the weight of the shells made loading devices an indispensable requirement, and the lack of experience in this field, caused by the preference for hand loading in former and lighter calibers, resulted in a serious loss of time in the designing stages. This disadvantage could have been avoided if battery personnel had not simple dismantled the loading devices of their 88-mm guns but had carried out their firing according to regulations.

87-88 The antiaircraft 88-mm shell had a weight of roughly twenty pounds (nine kilograms); the rate of fire of the gun was between 15 and 25 rounds per minute, according to the training status of the gun crews; the maximum altitude of fire was 33,000 feet; the maximum altitude at which a target could be combated with reasonable prospects of success was approximately 20,000 feet.

After introduction of the 88-mm Model 18 antiaircraft gun, the 75-mm guns were withdrawn from service and sold to foreign countries. Many of these guns found their way to Spain for use in the Spanish Civil War of 1936-1937.

The 88-mm Model 18 gun was under constant improvement. In 1936, field units received the improved Model 36. The inner tube was in three separate liner tube sections , so that the forcing cone section, usually the part most subject to attrition, could be replaced without any necessity to scrap the entire inner tube and replace it by a new tube from current production. Redesigning of certain individual parts had reduced the overall weight of the gun; the equilibrator had sturdier springs, which facilitated handling of the traversing and elevating mechanism; the lamp data transmission was improved; and a newly designed fuze setting mechanism was mounted on the gun , which did away with the necessity to carry it along separately. Two fuze setting cups were provided, so that the fuze setting process would not delay the delivery of fire. The trailer booms had also been changed, and the coupling for the mount in the riding frame had been redesigned to facilitate moving the gun into position and preparing for fire (Photos 58 and 59).

A number of minor imporvements were also incorporated in 1937: the lamp data transmission was changed to a follow-up system (Folgezeigersystem). This highly modernized gun was then redesignated as the 88-mm Model 37 Antiaircraft Gun. The ballistic performances of all three 88-mm guns, Models 18, 36, and 37, however, were the same.

The two-axle-mounted 20-mmantiaircraft guns (20-mm Model 30 AA Gun) issued to field units in 1932 did not meet the requirements of the troops, for which reason it was improved considerably already in 1933. It was given a single-axle carriage with a split-trail mount. Against the eventuality of its use in ground combat a 6-mm shield was provided. The riding weight, excluding the shield, was roughly 1700 pounds (770 kilograms), its weight in firing position roughly 990 pounds (450 kilograms). The solution found for the shield was initially rejected by the troops, and it was only after the campaign in Poland that the field forces urgently demanded a shield. If this had not been provided with wise foresight by the Army Ordnance Office and planned by the manufacturing firms in their first production series, a completely new design would now have become necessary. This shows how necessary it is in the designing stages to look

89-90 far ahead in stating the requirements, even if the troops, the General Staff and the War Ministry do not consider the innovations specified necessary. The principal improvements in the new guns was in the new mount system, which enabled one or two men to disengage or couple up the special type trailer with ease. For movement to elevated positions or roof positions, it was possible to dismantle the gun into six loads. It could also be man-hauled if necessary.

The gun itself was a fully automatic recoil loader with a tumble bolt, in which the pressure of the exploding gases automatically effected the loading and ignition of the shell and the extraction and ejection of the empty shell case. The ammunition was in magazines of twenty rounds each. The theoretical rate of fire was 300 but in practice only 190 rounds per minute. The movement in elevation was from minus 10° to +90°, and the muzzle velocity 900 meter/second. The gun had a muzzle brake, but this served primarily as a muzzle flash screen. Standard equipment included two muzzle brakes per gun, one with a diameter of 35, the other 41 millimeters. The use of these made it possible to regulate the functioning of the weapons within certain limits, since the shell case ejection and the general functioning of any gun is regulated by the distance of the recoil. A gun coming new from the factory was first used with the 41-mm muzzle brake. When the individual parts had become

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90-91 slightly worn, with a resultant easier working of the weapon, and accordingly a longer recoil stroke, the 35-mm muzzle brake was used. In extremely cold weather, which usually causes a tighter working of the moving parts, the difference resulting could be adjusted by use of the 41-mm muzzle brake. The maximum effective range of the gun was 1,760 yards (1,600 meters). Aspecial sight was provided for antiaircraft fire (Model 35), which was of the reflex type with an automatic computer. A linear sight was also supplied against the eventuality of the reflex sight being damaged. The equipment also included a special ground telescopic sight for fire against ground targets(Photos 60 and 61).

In antiaircraft combat the gun fired explosive shells which could also be used against live targets in ground combat. In antitank action it fired a 20-mm armor-piercing shell weighing roughly 5.25 ounces (148 grams) with a muzzle velocity of 830 meter/second.

This gun served primarily to protect moving columns, ~~xxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxx~~ artillery positions, and other important targets against low-altitude air attack. In the zone of interior it was also to be used against low-altitude air attacks. It was mounted on a single-axle special trailer, Model 51.

In addition, work had commenced in 1930 on the construction of a 37-mm antiaircraft gun. The 1,760 yard effective

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90-91 firing range of the 20-mm antiaircraft guns appeared inadequate and the effectiveness of the missile fired was also to be improved, for which purpose a larger caliber was essential. The first test battery of this new type reached the troops probably in 1933/34. The official designation of the new gun was 37-mm AA Gun Model 18 (3.7 cm Flak 18). It was a recoil loader with a centrally bolted breech-block; it fired an explosive shell weighing roughly 21.87 ounces (623 grams) with a muzzle velocity of 700 meter/second. For antitank combat it fired an armor-piercing shell of roughly 23 ounces (658 grams) with a muzzle velocity of 780 meter/second. The ammunition was packed in magazines of six and was loaded into the gun in these magazines. The theoretical rate of fire was 150 rounds per minute, but in practice between 70 and 80 rounds per minute. Its movement in elevation was from -5° to $+85^\circ$, and its effective range 2,640 yards. Its weight in firing position was 3,850 pounds, its riding weight, including its special trailer, was 7,380 pounds. This weapon was also used with the direct aiming method, using Antiaircraft Gun Sight Model 33 (Flakvisier 33), a reflex sight with automatic computer similar to that used with the 20-mm AA gun Model 30. Equipment also included a special ground telescopic sight with a magnifying power of 3x8 for fire against ground targets (Photos 62 and 63).

Since loading stoppages were a frequent occurrence in

19-92 the new weapon the troops refused to recognize it as suitable for use in the field, and it was frequently rejected. This fact was known to me personally. Having worked formerly for the firm of Rheinmetall I had good contacts with that firm, and so was able to arrange for mechanic of the firm to be at my battery when the first firing exercise with the new 37-mm gun took place in 1935 in order to instruct my artificer and troops. The three days spent by this fitter with my battery, during which he speedily remedied all loading difficulties and other troubles, gave the troops invaluable experience and was also of benefit to the firm. The firm now had actual knowledge of the difficulties of the troops, and the troops had gainedxxx excellent knowledge on the handling of the weapon. The effect was so marked that the battery for a long time enjoyed an excellent reputation, since it had far less trouble than practically any of the other 37-mm batteries. In 1936 the Inspector himself came to witness a battery firing exercise and was astonished to see how well the weapon functioned when properly handled, something he had not seen before and which he would not have believed. Cooperation between the troops and the manufacturing firms should be exploited to a far greater extent in this manner, for the benefit of the troops and to promote the work of weapons development by the firms. It would also serve to prevent from the outset many faulty appraisals of weapons.

92-93 When in 1936-37 the 88-mm and 20-mm AA guns went into action under actual battle conditions in the Spanish Civil War and proved highly satisfactory, a report was received from there rejecting use of the 37-mm model. This report was probably based primarily on a preconceived negative attitude toward this gun and stated as the main reasons for its rejection the impossibility to follow a target with the 37-mm gun, which it was already difficult to do with the 20-mm model. In actual fact the movements of the 20-mm gun were 29° in traverse and 4° in elevation per revolution of the handwheel. The comparative factors for the 37-mm model were per revolution of the handwheel

traverse 3° to (using speed gear) 7°
elevation 3.5°.

The improved 37-mm Model 36 gun had the following speeds of movement per revolution of the handwheel:

traverse 4° to (using speed gear) 10°
elevation 4.5

In spite of the adverse report thus received, it is a known fact that the 37-mm gun proved just as satisfactory when used in actual combat in Spain as the 20-mm and 88-mm guns.

The unreasonable and prejudiced false appraisal of the weapon nevertheless produced serious consequences: production and even development work was halted so far as the 37-mm AA gun was concerned, so that only a relatively small number of

93-94 these weapons were available at the start of World War II in 1939, and it was found later that this gun was particularly ef- efctive in combat, ~~xxxxxxx~~ This subject will be dealt with in more detail in later chapters of this study.

Returning to the previously mentioned case in which a factory master artisan participated infiring tests with the 37-mm gun I should mention that three days after his departure a serious failure occurred, which was to prove particularly valuable to the troops. After satisfactory performances on the one day, all guns on the next day, on which the master artisan was no longer present, functioned faultily after the second or third round had been fired. First thought was that this was due to faulty handling and servicing by the troops, but this was not the case. Finding rough surfaces and scratches while cleaning their guns, the troops had followed regulations to the letter and had added flowers of sulphur to the lubricant and this had made the lubricant too viscuous. After this very visuuous oil had been washed off with kerosese the guns again functioned normally. This washing with kerosene naturally took only a moment and at the end of the firing practice the guns had to be carefully cleaned to insure that no residue remained, which could have resulted in rust. However, the incident had provided a lesson on how to render the gun servicable in the shortest time if the necessity arose under actual battle conditions.

94-95 The above example shows that it is essential for every officer to be able to properly recognize the cause of any failure and also to know how to rectify it. Under no circumstances should he allow himself to become completely dependent on his weapons artificers or artificer officers and such personnel or rely exclusively on them. If he does so he runs the risk of his weapon through his fault failing in the few seconds during which it might have been used effectively.

The 37-mm weapons had been constantly improved. The goal was to remove the causes for the loading interferences which occurred time and again in the field, and to reduce the overall height of the structure, thus evolving a weapon which would offer the smallest possible target in ground action and at the same time improving its sturdiness; another objective was to reduce the weight of the weapon. The automatic parts of the weapon remained basically unchanged, but the split-trail mount using a two-axle carriage was exchanged for a triangular mount using a one-axle carriage (Photos 64 and 65). As previously mentioned, the aiming speed had been considerably improved, and the handlind was greatly simplified.

The advantages of the new model, designated 37-mm Model 36 AA Gun, were featured by its reduced overall riding length, the greater speed with which it could go into action and the reduced time required for displacement to new positions.

95-96 The weight of the weapon in firing position had been reduced to 3,400 pounds, its riding weight to 5,200 pounds. The new model also had a shield of 6-mm sheeting, which was in a number of sections and weighed roughly 400 pounds (185 kilograms). Its ballistoc performances were the same as those of the 37-mm Model 18 AA gun. It was carried on special type trailer Model 52. It was placed in field service in 1937 and production of Model 18 ceased.

Based on the 105-mm gun adopted by the Navy, industrial firms were also given instructions in 1934 to develop a 105-mm antiaircraft gun. The initial objective was to have a gun with the increased effectiveness of a larger calibed missile; a secondary objective was to have an increased firing range, although this was not the decisive point at the time , since a weapon was available in the 88-mm gun with an altitude of fire which was not inferior to the altitude performances of aircraft. The main idea was to use the new gun mounted on railcars. This weapon had a muzzle velocity of 880meter/second, and its maximum altitude of fire was approximately 40,000 feet (12,000 meters). Its altitude of fire for effective action against aircraft was 23,000 feet.

It was considerably heavier that the 88-mm AA gun, and more mechanical power had to be used to achieve the aiming, loading and other speeds essential in an antiaircraft gun.

96 As the first gun produced with mechanical aids of this type, many initial defects naturally had to be remedied. The ammunition was too heavy to achieve the necessary rate of fire by hand loading, and the loading mechanism provided gave the gun a rate of fire of 15 rounds per minute. The first trial models of the new weapon were delivered to the Army Ordnance Office for proving in 1936 and by the beginning of World War II in 1939 the first batteries already had 105-mm antiaircraft guns.

It would be wrong to omit mention of the fact that both Krupp and Rheinmetall had been working on the construction of a 150-mm antiaircraft gun since 1937. Both firms completed their development projects by the end of 1939, and test models were delivered to the technical proving departments prior to the start of World War II.

The antiaircraft guns thus available at the start of World War II in 1939 were as follows:

88-mm AA gun Models 18, 36, and 37	As standard items of field unit equipment
37-mm " " " 18 and 36	
20-mm " " " 30	

105-mm AA gun Model 38 a few with troops under field tests.

AMMUNITION

The high standards of performance which had to be

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96-97 required of antiaircraft guns made it necessary, for barrel conservation, to develop a po der with a lower flash temperature than that of the nitrocellulose and nitroglycerine powders used in artillery ammunition by practically all armies.

Nitrocellulose powder has a flash value of 950 thermal units, and in addition it was still at that time highly moisture absorbent.

Nitroglycerine powder produced flash values of between 1,250 and 1150, 950 or 820 thermal units according to the percentage of nitrocellulose and the type and quantity of the stabilizers added to it.

Suitable propellants with a lower flash temperature could not be produced with nitroglycerine powder.

The higher the burning temperature of the powder however, the greater is the erosion of the gun barrel. If shells with copper rotation bands are used, considerable erosion occurs primarily at the forcing cone, which soon render the barrel unservicable.

Experiments had therefore been in process since 1930 with various explosives, and the powder factories carried out very careful and detailed research work in efforts to find a substance suitable to take the place of nitroglycerine powder. The requirement was that the new substance must have at least a propelling power equal to that of nitroglycerine powder but a considerably lower burning temperature. Colonel Dr. von

97-98 Gallwitz, at that time specialist for propellants in Weapons Proving Branch 1 and later killed in action in Russia, merits special mention in this connection. Working assiduously in cooperation with the appropriate industrial concerns, he finally succeeded in finding a powder which could be submitted to detailed tests and examinations from 1936 on. Diethylglycoldinatrate (Diaethylenglykoldinitrat)is a product chemically related to nitroglycerine, easily manufactured from simple and cheap raw materials, and used in similar admixtures with nitrocellulose to produce diglycol powder . A highly important factor was that factories could convert to the mass production of this powder in the largest quantities without any large changes in their installations and processes. This provided a powder giving the same propellant performances as the powders formerly in use, at a heat of only 700 thermal units. Besides its excellent ballistic properties, however, the new powder presented other advantages:

It had considerably better gelatinizing properties than diglycoldinitrat

the manufacture was less hazardous than that of diglycol powder

the powder capillaries (Pulverroehren) were smoother and more elastic and

its chemical stability was more favorable than that of the nitroglycerine powders.

98-99 Furthermore, the use of certain additives, such as potassium sulphate, served to reduce the muzzle flash considerably. All of these advantages were of very particular significance for antiaircraft guns.

A change was also introduced in the delivery acceptance procedures. Instead of requiring, as in the past, that a stipulated quantity of the powder ~~xxxx~~ tendered for acceptance must show a stipulated performance, the new regulations stipulated that powder with its inherent moisture and in weight quantities suitable for experiment, must achieve the established muzzle velocities. The weight to be used was then fixed at the acceptance procedures, and could vary from delivery to delivery.

As was the case in all branches of the artillery, the weight of the finished powder product was checked and it was separated into different weight classes. In this way it was possible to balance any deviations ~~xxxxxxx~~ from the normal weight of shells, which resulted in differing ballistic performances.

Tests lasting a number of years were also carried out with steel shell cases to provide against the shortage of brass which would necessarily result if brass shell cases remained in use. The outcome of these tests was that the troops were finally issued satisfactory shell cases of steel. In the case of the antiaircraft artillery, however, serious difficulties occurred

99-100 repeatedly, particularly when new guns with particularly high levels of performance were taken into service, which made special measures inescapable. Here, the construction of the barrels in sections also played a very disturbing role, a subject which will be dealt with later in this study, since setbacks and new requirements occurred right up to the end of the war in 1945.

Particularly careful tests were carried out with the iron rotation bands for shells. In the end these efforts were successful and a rotation band of sintered iron was produced in 1938 which was not only equal to but even superior to the copper bands. The recommendation that the new bands should first be introduced in the antiaircraft artillery, as the largest single user of ammunition, met with considerable resistance. The Inspectorate categorically refused to serve as a guinea-pig in the matter of iron rotation bands, in the knowledge that experience in World War I from 1914-18 had shown that these introduced a number of disadvantages. It as by no means easy to convince the Inspectorate that the new bandswere even superior to the old.

A number of setbacks occurred which will nowbe briefly dealt with. In tests with a number of 88-mm Model 18 AA guns, a considerable increase in barrel attrition suddenly became

100 evident, which appeared to vindicate the doubts expressed by the critics. However, it was then found that the guns in question had been used previously to fire shells with copper rotation bands, whereas all tests in the past had been with unused barrels. Tests in which copper and iron bands were used in succession showed very bad results. Besides wide deviations in the muzzle velocity, barrel attrition was also far higher than when copper bands were used exclusively. In the case of new barrels firing shells with rotation bands of sintered iron it was found that there were practically no signs of erosion at all in the force cone section and rifling grooves and lands. The muzzle velocity decrease was also far smaller and slower than in barrels firing shells with copper bands. Erosion was now actually greater at the muzzle than at the force cone. This showed that the construction of the barrels in separate sections, which involved numerous difficulties in manufacture, had suddenly become of less importance than in the past. The muzzle velocity was admittly slightly less with sintered iron bands than with bands of copper, but this could easily be adjusted by a slightly increased propellant charge. Strangely enough external ballistic factors also had a slightly different influence, resulting in a shorter range for the shells with iron bands. This defect was rectified by a small change in the pitch of the shell.

101 Setbacks occurred time and again when new firms were awarded contracts to manufacture the iron bands, since these firms thought they could avoid what they considered the unpleasant process of sintering. Instead they tried using very thin steel wires, but all of their attempts with substitutes failed.

Unfortunately, the war started before a final decision was made on the use of iron rotation bands, and the large bulk of the ammunition held in stock was with copper bands. This was a most unfortunate circumstance, since the conversion then had to take place under conditions of war. The result was that at times one and the same gun was firing shells with copper and others with iron bands, which caused more frequent failures and greater barrel attrition. If the iron bands had been generally adopted for antiaircraft shells in 1938, as recommended by Weapons Proving Branch 1, these complications would not have occurred during the war, a subject which will be treated in the following chapters.

Conversion from the powder-train time fuze to the mechanical time fuze was completed between 1919 and 1932, and has therefore been dealt with in previous chapters of this study.

In the light of experience during World War I measures were also taken to provide for the use of antiaircraft units in action against tanks. Tests at the Jueterbog firing ranges of the artillery had also shown that no other gun was as

101-102 suitable for action against fortifications as the 88-mm AA gun. In the 1932-1939 period, very special emphasis was therefore placed on the development of particularly effective armor piercing shells. These were given a solid core of wolfram and were fired with the highest muzzle velocity achievable. Their effectiveness was due to their force of impact, and their purpose was to pierce the plate or other armor and detonate inside the protected area. In the case of the antiaircraft artillery guns with their extremely high muzzle velocity a particularly difficult problem was that of phlegmatizing the explosive charge to such a state that it would not explode immediately on impact but only after the shell had penetrated into the bunker or other target under fire. The Antiaircraft Artillery Inspectorate insisted categorically on forcing the development of the suitable explosive charge to a speedy conclusion; Weapons Proving Branch 1, on the other hand, which was responsible for this project, refused categorically to precipitate maters. The Branch wanted to insure definitely that the troops were not exposed to hazards which would have been unavoidable if the newly developed ammunition were introduced for use without first having been adequately tested. Furthermore, the Branch held the view that the hard core armor piercing shells would be adequately effective against tanks and fortifications even without any explosive charge.

102-103 Events proved the assumptions of Branch 1 to have been ~~xx~~ correct when in 1938 the bunkers at the Czechoslovakian frontier actually succumbed under fire with solid core armor piercing shells without any explosive charge. The petetrating missiles and the fragments of wall, or in the case the fragments of armor plating, caused such havoc inside the bunkers or tanks, that the crews were incapacitated. It was 1939 before success was ~~achieving~~ achieved in producing an explosive charge so phlegmatized that it could be used in armor piercing shells. This naturally increased the effectiveness of such shells.

Knowing that wolfram was a metal which would not be available to Germany in adequate quantities in the event of a war, research commenced also in the 1930s to find some substitute. Specially hardened steel was one solution, but the hardening process was complicated and very few firms had the necessary specialized personnel to manufacture really satisfactory and reliable ammunition of this type. Furthermore, when ammunition was held in stock for lengthy periods it was found frequently that cracks caused by the tempering process had damaged the armor-piercing head of the shell and rendered it useless. During the war, however, it became unavoidable to use emergency measures of this type.

On the basis of experience in the use of hollow-charge explosives in action against fortification works, attempts

103-104 were made in 1936-1938 to produce hollow-charge shells for action against tanks and similar targets. In the initial tests, however, the strains to which it was exposed in firing usually destroyed the hollow-charge, and it was only after long series of tests that these difficulties were surmounted. Shells of this type had to leave the gun barrel with a lower muzzle velocity than normal shells. This was essential both to reduce the stress on the shell at firing and to insure the desired effectiveness of the hollow charge. The shell had to be in contact with the target at the moment when the hollow charge detonated, and not already have bounced or rolled off the target because of an excessive impact speed. Reduced muzzle velocity, however, reduced the zone of fire and also firing accuracy, for which reason the solid core shell had to be given preference. On the other hand, the xxxx effectiveness of the solid-core shell decreased in relation to the distance of the target from the firing gun, since its penetrating force diminished, whereas the effectiveness of the hollow-charge shell remained unaltered, regardless of the distance. Both types of shells thus had advantages and disadvantages, for which reason both were further developed and introduced for use.

The ammunition types available for the various guns at the beginning of World War II were as follows:

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88-mm Antiaircraft Gun

88-mm high-explosive shell with time fuze
fired with a muzzle velocity of 820 meter/second
Weight roughly 32.34 pounds (14.7 kilograms)

88-mm armor piercing shell with impact fuze
fired with a muzzle velocity of 800 meter/second
weight roughly 34 pounds (15.3 kilograms)

20-mm Antiaircraft Gun

20-mm high-explosive shell with tracer, self-destroying
after flight of 5.5 seconds = 2,200 yards
fired with a muzzle velocity of 900 meter/second
weight roughly 4.5 ounces (120 grams)

37-mm Antiaircraft Gun

37-mm high-explosive shell Type 18 with tracer, self-destroying after flight of 10-14 seconds = roughly 4,400 yards
fired with a muzzle velocity of 820 meter/second
weight roughly 22 ounces (623 grams)

37-mm armor piercing shell with tracer
fired with a muzzle velocity of 770/meter/second
weight roughly 23 ounces (658 grams).

In the Spanish Civil war of 1936-37 increased participation by the antiaircraft artillery units in ground combat was required, so that the manufacture of the necessary ammunition with impact fuzes had to be accelerated. Tests with the fuzes used by Army artillery resulted in failures and barrel bursts. Special impact fuze types had to be developed and manufactured. These new types of fuzes were supplied to the field units in

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105 1937 so that the 88-mm antiaircraft guns then had

88-mm high explosive shells with impact fuze
muzzle velocity and shell weight as shown above for
the 88-mm high-velocity shell with time fuze

INSTRUMENTS

At the start of World War II in 1939 there was available for light antiaircraft weapons a rangefinder with a base of one meter developed by the firm of Zeiss in 1926 (photo 66). It was a stereoscopic rangefinder waith a range capability of 233 to 8,800 yards and an accuracy tolerance of roughly 550 yards at a distance of 4,400 yards.

The 88-mm batteries had a 4-meter base rangefinder (photo 67), also a panoramic model, with a range capability of 740 yards to 11,000 yards. It was handled by three men, one of whom gave the traverse and the second the elevation readings, so that the actual rangefinder operator could concentrate completely on the actual range readings. Constant practice was necessary with these instruments to maintain the operating ability of the personnel. The instrument needed adjustment almost every two hours, according to current weather conditions.

It is necessary to mention here, however, that troops were required to defend themselves with their own weapons, by rifle or machinegun fire, against low-level air attacks.

105-106 This applied to infantry troops, transport columns, etc., and experience had shown time and again that massed rifle fire, even though no aiming devices were available for the purpose, produced better results that fire by a single machine gun. This is probably due to the fact that when a large number of men fire at an airborne target, they do so from numerous directions, so that one or the other of them by chance, in very favorable circumstances, is more likely to score a hit than fire coming from machine guns in only a few positions. It was often said ironically that with so many riflemen all delivering faulty fire, the large number of errors cancelled out each other so that one was bound to score a hit. Although this does sound spiteful, there is nevertheless some truth in it: repeated mistakes can cancel out each other and in the end lead to the right result, namely to a successful failure.

Machine guns had a ring and bead sight for antiaircraft firing. The readings of the ring and bead sight were calculated on the basis of aircraft speeds of 90 to 180 miles. The rate of fire was 450 rounds per minute and the muzzle velocity 815 meter/second.

Circumstances were very different in the case of the 20-mm and 37-mm guns. These were equipped with an antiaircraft sight constructed and tested in 1927. It had a computer, a reflex sight and a parallelogram linkage system. Target speed had to be set on the

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106-107 Target speed had to be set on the computer. The speed was estimated or it was known for the target attacked. The sight could be set for target speeds of from 0 to 150 meter/second. The figure for the range reading taken from the 1-meter-base rangefinder also had to be set on the computer, the rangefinder having an operating range of from 330 to 3,300 yards. Furthermore, the man adjusting the antiaircraft sight had to set the direction of flight of the aircraft and any changes in altitude by the ~~flight~~ target-flight- direction indicator. The whole instrument thus functioned very precisely on the basis of computed factors, the important point being that constant training and practice schooled the personnel to compute these factors as accurately as humanly possible. An interesting point is that these computers were copied by many countries, often in the most simplified forms.

Originally, each 20- or 37-mm antiaircraft gun had been equipped with two rangefinders. One of these was for use when the operator called out the range reading directly by voice to his gunner. The second was for use by the gunner himself and enabled him to see how his fire was placed, and to adjust his aim accordingly. For this purpose he had to detect that point of the tracer trail which was closest to his target. Without a rangefinder this would be possible at ranges up to approximately 660 yards, due to the distance between the two eyes, which is

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107-108 artificially increased by the use of a range finder. Field-glasses or a telescope would not thus widen the base of vision and therefore can not be used in place of a rangefinder.

Besides these antiaircraft sights and rangefinders the equipment of light antiaircraft weapons included a linear sight (Photo 68) set for ranges between 330 and 1,760 yards and for target speeds betwee 10 and 150 meter/second. Here it was necessary to set the factors for

range, according to readings from the rangefinder;
the direction of target flight and changes of target altitude determined by the person handling the sight by means of his observations of the target.

Firing with the antiaircraft sight was given preference since it functioned with more precise data factors.

Provision was also made for the aiming of fire by observation of the tracer trails, but this type of aiming was only to be practiced over short ranges of less than 330 yards or as an emergency measure under surprise attack leaving no time to set the proper sighting devices. Unfortunately, the tracer trail and the mistaken belief that observation of this trail was the right thing to do, misled gunners into continuing to aim by the tracer trail at ranges greater than 330 yards, even when they had the proper data from their instruments. It proved a grave error of omission that nothing had been done during peace to severely suppress such practices. This omission

108-109 later caused us incalculable harm. The Russians, for example, did away with tracers in a large percentage of their ammunition, and with the use of the same aiming devices used on the German side, achieved good results, as German airmen experienced and confirmed time and again.

For fire against ground targets, these guns used the normal ground fire telescopic sight with a magnifying power of 3x8.

Antiaircraft fire with the 75-mm and 88-mm guns required special equipment which automatically computed and predicted the point of missile-target intersection. Observation of the distance between the fire delivered and the target from the ground would simply have been impossible without aids. Fire correction based on such unreliable observations could never have produced satisfactory results. Target travel factors and possible changes of course in the time between the first round fired and the following shellburst to the time of release of the next round fired with the aim corrected on the data thus secured created an entirely different situation which was no longer valid for the second round. For this reason it was imperative to have, before fire was opened, the necessary data on all influencing factors resulting from target travel, ballistic factors, wind and weather, and to compute the firing data from these factors. To this end a number of firms had carried out the necessary research and development work

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109-110 for the construction of a fire control director. Research and development contracts for this purpose had been awarded to the firms of Hartmann & Braun; Kuhlmann, in Wilhelmshaven; and Gelap. The solution adopted was the Fire Control Director Model 36, which evolved from the former Model 27, and was designed and constructed by the firm of Zeiss in accordance with instructions from Professor Pschorr. (Photos 69 and 70). In this model the the rangefinder was mounted on the main instrument, so that target factors for lateral and elevation movement were supplied directly to the computing instrument when it was aimed at the target. It functioned on the geometrically linear principle. Target altitude and the slope range were determined by sighting the target through the attached rangefinder an the factors thus obtained were set on the range recording cylinder of the instrument. The instrument computed the firing data sxxikxxbxxixxxf for elevation, traverse, and fuze setting on the basis of the factors determined for target travel direction, target speed and the time of missile trajectory flight required to the point of target-missile intersection. The factor for the time lag in data transmission and gun loading had to be set, and thus could be adjusted continuously. Adjustment cylinders were included for wind and atmospheric density as well as current condition of the barrel, so that allowances could be made for these factors.

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109-110 and included in the data transmitted to the guns by means of the mechanical (lamp) system or by word of mouth. It is hardly necessary to mention that allowances were also made for difference in position between the gun and the separately positioned fire control director. As a rule, the fire control director was set up some distance from the battery position to prevent interference with its functioning and also in order not to expose it to weapons fire if enemy planes happened to attack the battery. Three men were required to handle the rangefinding equipment and ten men to attend to the data recording cylinders: One took the readings for target range or altitude and another set the appropriate factors on the cylinder; the third man tracked the target direction of flight at the plotting table, and the fourth determined and set the target speed. The rest attended to the settings for wind, atmospheric pressure, and current gun performances for firing altitude, traverse and fuze setting.

For successful fire it was essential that the target continued to travel in a straight line and at the same altitude or in the same angle from the moment target data determination commenced to the the moment of shell explosion and that its speed remained constant. If the target changed its course just prior to fire, it was th necessary correction could be made at the plotting

110-111 This was an easy matter and easily understood, so that such last moment corrections were usually successful. Provisions were made for telephonic data transmission if the mechanical data transmitter failed.

Fears were entertained that this equipment would be too sensitive and would therefore be subject to frequent interferences or total failures, but these fears were not confirmed in practice, so that in later models it was found possible to dispense with the auxiliary fire control director provided fof for each battery in the tables of organization and equipment. The instruments naturally had to be calibrated from time to time, and the range finding equipment had to be adjusted approximately every two hours according to current weather and other conditions. This was done by precsiely surveyed points in the terrain or, in conditions of poor visibility, by means of a calibrating instrument placed on the rangefinder. The weight of the Model 36 fire control computer equipment set was roughly 3025 pounds (1,375 kilograms); together with the trailer the total weight was 6490 pounds (2,950 kilograms).

Besides the equipment just described, each battery had a Model 35 auxiliary fire control director weighing only roughly 430 pounds (195 kilograms), with trailer roughly 1,990 pounds (905 kilograms). This was an instrument functioning on the target angle velocity system developed by

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111-112 the Navy and adapted for use in the Air Force. It was mounted separately from the rangefinder and the data factors procured with it for range, elevation and traverse were transmitted by telephone to the guns. It was developed by the firm of Gelap and also manufactured by that firm. By measuring speed, acceleration, etc., the instrument supplied relatively accurate data for any target course. The correct relation of the osculating curve (Schmiegungskurve) to the true direction of flight was obtained from the lateral and altitude angles and the range was calculated by multiplying the time differences with the time of missile trajectory flight to the computed point. By means of these comuptations an approach solution was then sought for the various flight patterns which actually approximated the direction of actual flight, and it was also possible in this way to determine a sloping flight. In this respect the instrument was superior to the Model 36 Fire Control Director, while in all other respects the latter was the better of the two. The Model 35 Fire Control Director (Photo 35) operated without electrical devices and was thus independent of power supplies. All factors were computed exclusively by mechanical means. It was developed in the 1930-35 period and supplied to the troops from 1935 on.

112-113 Generally speaking, this equipment was not popular with the troops because the firing data it supplied was not as accurate as that from the Model 36 Fire Control Director, and also because various complications were caused by the telephonic data transmission. During the war it was used frequently with captured batteries and the Army also used it in its Army AA batteries, since the output of Model 36 and and later of Model 40 was too small to equip all batteries. Since the Army AA batteries were not required in the same measure as those of the Air Force for high-altitude targets, they had to get along with the auxiliary fire control director equipment.

In 1934 a new development project started under Staff Technologist Kuhlenkamp at the firm of Carl Zeiss. During the developing stages the new instrument was known as the K "apa Model; later it was supplied to the field units as Model 40 Fire Control Director, but this was only after the war had started in 1939.

A subject which cannot be omitted here is that of fire by heavy antiaircraft batteries relying on an rangefinder, a system of fire known as "free firing." This system of firing evolved from the methods of World War I and a few of the older age class antiaircraft artillerymen were still masters at it. After the development of properly functioning

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112-113 fire control equipment, however, it could only be considered as a waste of ammunition, for which reason it was prohibited in 1940, shortly after the start of World War II. With this prohibition the Peres rangefinder, until then still an item of equipment, was no longer supplied to the units.

The training given in the operation of Model 36 Fire Control Director was exemplary. By means of constant checks and exercises rangefinder personnel were kept continuously at a high standard of performance. Optical tests for all personnel operating fire control director equipment were conducted at least once weekly. During these tests, as well as later during firing exercises, it was possible to have each member under precise supervision. A very carefully thought out method made the assment of the test results possible, the only factor not being taken into consideration being fuze timing dispersals. During exercises with live ammunition each round was also subjected to a minute examination to determine the results of errors by the individual members of the servicing crews. This thorough training did not fail to produce commensurately successful results at the beginning of the war. It was so thorough that it even had adverse effects later in the war when new equipment based on more modern principles was to be taken into use. However, the subject will be dealt with more fully later.

113-114 Unfortunately, an equally thorough examination of the functional performances of the individual crew members was not possible in the case of automatic weapons. The higher levels of command in this branch, where most posts were held by personnel coming from the Army, even opposed any assesment of firing performances of the type customary in the heavy batteries. These circles failed to comprehend the value of such strict supervision over the gun crews. If the system had been introduced here, it would certainly have been possible to raise to even better standards than those actually achieved, the firing performances of the light antiaircraft artillery forces.

In 1935 the Antiaircraft Artillery School received instructions to work out assesment methods for light antiaircraft artillery units similar to those used in the heavy branch. The project was frustrated by the difficulties encountered, and it must be admitted here, that the School only tackled the problem half-heartedly. Otherwise, the faultiness of "tracer trail observation" would have been discovered at that early stage and prohibited, just as "free firing" was prohibited in the heavy antiaircraft artillery. It would also have been discovered that the adjustments made by means of the direction indicator and the regulator (Regler) in accordance with existing regulations were wrong, since

114-115 the factor for one and the same error was set twice, thus giving false results. This fact was recognized by the battalinns which, contrary to regulations, introduced and even improved for light antiaircraft weapons the assesments introduced by the School. These assesmants were no light matter, but these units deserve recognition for carrying them out, since it is due to them alone that at least the most glaring errors in the regulations were deleted. During firing exercises it was also clearly obvious that batteries which had been compelled to carry out this program of supervised training achieved better results than other batteries. Unfortunately, however, the School was able to enforce its demand that the field units should not be authorized to conduct such tests with light batteries. It must be admitted, unfortunately, that unjustifiable service jealousies may have played a role here, the fear being that this meticulously detailed work would hamper and unfavorably influence the weapons in their flexibility and speed of action. This led, however, to the gunners being trained to be superficial in their aiming. That these circumstances did not produce serious results is no evidence that ~~the fact is not proven~~ that more thorough training and a clearer realization of the basic factors in firing would not have produced better results. I personally am convinced of this and fear that

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115-116 there is still a tendency nowadays to treat these matters toosuperficially. This matter will be gone into more closely later in the present study, sinceit continued throughout the war to hamper further progress in this field. Notice was taken only of the evident value of this weapon for its effectiveness, speedy action, quick target recognition, the spee and suddxnness with which it could open fire.

The labor ex pended in the manufacture of the high-precision instruments required for a heavy battery equalled that required in the manufacture of four heavy guns. In the case of the light batteries, the cost was even higher. This serves to illustrate the ext eme importance of precision mechanics for an air force. Lacking a highly developed industry pro-ducing high precision instruments it would have been impossible to equip the German Air Force with these direly important instruments, and although this branch of industry had reached very high standards in Germany, instruments of this type were always in very short supply and there was a constant search for ways and means to equip the units with the indispensable instruments required to obtain reliable firing data.

SEARCHLIGHTS AND ACOUSTIC DETECTION EQUIPMENT

The development of searchlights for antiaircraft artillery purposes was also resumed in the 1930s. It had to be assumed that enemy air forces

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124-125 5. <u>The Army Ordnance Office and Antiaircraft Artillery Development in the 1932-1939 Period</u>. Whereas the preceding section of this study dealt with work done directly and exclusively for development of the antiaircraft artillery in the 1932-1939 period, the present section will touch on development projects initiated by the Weapons and Equipment Proving Branches of the Office during the same period but which had not yet been concluded by the start of World War II.

In the field of ammunition the major developments have been dealt with in the previous setion. These were: the development of steel shell casings, Guanidin powder with a low burning heat, iron shell rotation bands, and armor piercing and hollow charge shells for the antiaircraft artillery.

In the field of gun development, mention must be made, besides guns themselves, to the problem of gun barrel structure. The subdivision into a breechblock piece, a jacket tube and an inner tube with tube liners in separate parts was indubitably a considerable step forwards. It was now no longer necessary to replace an entire gun barrel when only a small part of it had become unservicable. ~~For this reason the research continued for still further improved~~ The difficulties encountered in manufacturing gun barrels of this type and the corresponding barrel parts was still a

116-117 assumed that enemy air forces in any future war would also attack at night, as they had done during World War I, in 1914-1918. Although authorities on the subject of air operations considered that night attacks could only be carried out by individual aircraft, preparations were made against the eventuality and the 60-centimeter searchlight was developed for the light antiaircraft weapons (Photo 72).

This model had a suspended invert-high-performance lamp with a parabolic mirror of glass, giving an illuminating intensity of 150 million Haefner-candlepower. Under favorable conditions of visibility and with its beam concentrated it had a penetrating range of 5,000 meters (roughly 5,500 yards). It was manufactured by the firm of SSW, was mounted on a Special Type 31 trailer, and issued to the units in 1938. Current was supplied by a 90 ampere generator.

For the heavy batteries use was made initially of available 110-centimeter searchlights furnished by the engineer arm for the purpose. However, these were soon replaced by 150-centimeter searchlights developed and manufactured by three firms (SSW, AEG and Koerting) as test models. The first batteries were equipped with these models for experimental purposes. The models from the firms of SSW and Koerting had labyrinth reflectors, that from the firm of AEG (Allgemenie Elekrizitaet Gesellschaft=General Eleczric Company) a conical reflector

116-117 (Blende). The experience gained with these experimental models served for development of the Model 37 150-centimeter searchlight which became standard unit equipment in 1937 (photo 73).

Inside the searchlight casing was a suspended self-regulating high-performance lamp. The light beam was reflected by a parabolic reflector of glass. It had a conical (~~XXXXXX-XXXXXX~~) reflector which had the advantage over those used in the past that it was considerably lighter in weight. The searchlight had ~~xxmxgxifxingxpmxwerxof~~ illuminating power of 1,100-1,200 Haefner-candlepower and under favorable conditions of visibility and with a floddlight beam could detect targets at a range of between 6,000 and 9,000 meters (roughly 6,600 to 9,900 yards). With a concentrated beam it could hold targets at ranges up to approximately 13,200 to 16,500 yards. Electricity was supplied by a 200 Ampere generator. (photo 74).

A ring-shaped sound locator was used to locate the target (Photos 75 and 65), which under favorable conditions had a maximum sweep range of 12,000 meters (roughly 13,200 yards). It was equipped with a sonic lag computor which was to calculate the necessary lead, and was designed for target speeds up to ~~XXXXX/XXXXX~~ 100 meter/second. The object was to have the target in the floodlight beam immediately it was

117-118 switched on without any necessity to first search for it. Since sonic speed is subject to temperature, wind flow, and wind direction, provisions were made to compensate for differences in that speed. The searchlight was handled by three men, one of them for altitude locating, the other attending to the sonic lag computor. The accoustic locator functioned with a tolerance of plus-minus 2°, an important factor being naturally the thoroughness with which the crew worked. Special attention was devoted to the training of the operators of sound locators, the training program for such personnel being similar to that for rangefinder personnel in the antiaircraft artillery. The accoustic factors, corrected by the sonic lag computor, were transmitted either by telephone or ba mechanical indicator (lamps) to the searchlight, the system being the same as that used in transmitting target data from the fire control director to the guns. To insure prospects of success in searchlight operations it was essential to employ at least a complete battery of nine searchlights together. In fact, if at all possible the whole battalion of three batteries was to be kept together for really effective searchlight operations. In antiaircraft artillery fire at night success hinged completely on good and reliable illumination. Lacking searchlights, the only possibility, and that

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118-119 with only very dubious prospects of success, was to deliver barrage fire or fire directed on the basis of acoustic locating, a system which however, was only further perfected around 1940. However, both of these methods produced results far less effective than fire directed at a target illuminated by searchlights.

Colonel Weiss rendered especially valuable services in the development of searchlights, the training of searchlight operating personnel, and the training of airmen in searchlight supported air operations. If it had not been for his earnest insistence on such training, defense against enemy night attacks would have been completely impossible at the beginning of the war. In spite of this, however, it must be stated here that not enough consideration was given to the whole complex of searchlight training. For example, searchlight operating personnel had little faith in the acoustic detector equipment. For this reason, the searchlight unit commanders seriously neglected the requirement to cover their searchlight beam pending receipt of the target data from the acoustic detector. Instead, they simply directed their beams upward and searched for the target by circular or light cordon maneuvers.

The regulations governing searchlight operations were also defective, if not totally inadequate. These regulations required that the searchlight direction was to follow adjustments only very gradually when the detectors reported a

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119-120 change in the target course. This change was indicated by the detector later than its actual occurrence, because of the sonic travel lag, and therefore a sharp adjustment should have been made to again spot the target. Such facts were only learned through actual experience during the war and then came the added complication, that personnel had to unlearn their former training and adapt themselves to the new. This was a particularly hampering factor, and the more thorough peacetime training had been, the more difficult it was to surmount it. Many otherwise excellent personnel failed to perform satisfactorily when new regulations were issued, and simply could not be retrained. It was found more easy to train new and inexperienced personnel with new equipment than to retrain experience soldiers who had become familiar with the older types of equipment.

OTHER AIR DEFENSE EQUIPMENT

BALLOON AND KITE BARRAGES.

The problem of balloon and kite barrages was also taken up again in the 1930s, Based on experience gained in World War I, appropriate preparations were made for the use of such barrages against aircraft attacking at low altitudes. According to current weather conditions, use was made of kites or balloons for these purposes.