120-121 At wind velocities below 6 meter/second kites could not be used, whereas balloons were unsuitable for barrage purposes at wind velocities above 12 meter/second. It was relatively easy for aircraft to find their way through a single line of suspended wires. For this reason, barrages were to be, if at all possible, in three successive lines arranged chequerboard fashion echeloned in depth. On an average, the successive lines were roughly 440 yards apart. The altitude to which the balloons could ascend depended very largely on the materials available, light-weight balloon envelopes and light-weight wires being the two determining factors, but the gas filling also being a very important consideration. The maximum altitude of balloon barrages (Photo 77) was around 3,850 yards, whereas kite barrages (photo 78) proved effective up to altitudes of 5,500 yards.

Barrages of these types were set up either along the presumed enemy approach routes or around important defense targets. An aircraft colliding with one of the wires usually crashed immediately, or at least as a rule was so badly damaged that it could not continue in flight for any considerable distance.

Experimental battalions were established by 1939 and equipped with the first experimental items of equipment. Training had not yet been completed, so that the personnel

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121-122 still had to learn a lot from experience in their first operations under actual war conditions.

Numerous accidents occurred in which our own aircraft were involved. This was not due to neglect on the part of the balloon barrage units, but to inattention on the part of the airmen concerned, who had failed to inform themselves on the positions of balloon barrages and thus flown into the barrage xxxxxxxx although, these positions were made known at all air bases.

CAMOUFLAGE AND DUMMY INSTALLATIONS.

This subject also merits mention here, since it played a highly important role in 1942-1943.

Such installations had proved highly effective already during maneuvers in 1938. At that time airmen still had to rely exclusively on ground observation and had to be able to see their target in order to attack it.

In order to deceive the enemy, camouflage equipment had to be adapted to the local terrain , or had to represent an exact duplicate of the targets they were intended to simulate. For this reason the various items of equipment required could not be produced in masses, as was the case with other types of equipment. Every officer assigned a camouflage mission was allowed wide limits within which he could use his own initiative. The greater the variety of

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121-122 ideas incorporated in the construction of a dummy installation of this type, the better were its prospects of success. No s ecial training was given in this subject prior to the war, and it was only during the first stages of hostilities that the necessary experience was acquired, after which quite a number of excellent experts emerged.

TRAINING AIDS AND DEVICES FOR WEAPONS AND EQUIPMENT PROVING

The subjects under this heading will not be treated in detail here, but it would be an unpardonable omission to make no mention at all of them. Without proper aids, training would have been impossible and any chance of success in war would have been jeopardized. The instruments used in the training of rangefinder and acoustic detector personnel have been mentioned in the preceding sections. In optical tests and in firing exercises with live ammunition it was also not possible to dispense with such instruments. Theodolites with photographic equipment were used to determine the trajectory of each round fired and the results were carefully analyzed. Air firing tables could only be compiled with properly analyzed photogrammetric recordings. The instruments used for such purposes were extremely expensive and had to be handled and cared for with commensurate care. This in turn made proper training in the use and maintenance of

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122-123 these instruments an inescapable necessity.

The firm of Askania was employed on projects developing instruments of these types from 1930 on, and other firms were also called in to participate in the program so that it would be possible to supervise the training of the troops and to improve their performances constantly.

Instruments in this category were also required in the proving of weapons and equipment to determine whether they met the required standards. The troops had practically nothing to do with these activities, which were nevertheless of major significance to insure success in combat operations. Work in these fields continued without interruption , continuous progress was made, and electronics, already at that time, were beginning to play a role in these instruments.

MOTOR VEHICLES

In the preceding accounts given of various items of equipment, mention has also been made repeatedly of the vehicles serving to render them mobile. As a rule, use was made of motor vehicles of types already used by the Army. Only when this was absolutely essential were special vehicles called for, for the construction of which the appropriate proving branch in the Army Ordnance Office, namely Weapons and Equipment Proving Branch 6 (Wa.Pruef. 6) then placed

123-124 contracts with industrial firms.

In summarizing, a list follows of the various special type trailers in use and the weapons and other equipment for which the were used:

Trailer Type	Used for Weapon of Equipment Model
Single-Axle Type 51	20-mm AA Gun Model 30 60-centimeter Searchlight
Type 52	37-mm AA Gun Model 36
Type 53	Auxiliary Fire Control Director
Type 104, consisting of two identical twin-axle pieces	37-mm AA Gun Model 18 Fire Control Director Model 36 150-centimeter Searchlight Ring-shaped xxxxxtix sound detector and locator Power unit for 150-centimeter searchlight.

124-125 source of very serious concern, however, since only really big firms of very high standing could produce them. For this reason the search continued for other methods of gun construction.

An American Major Zornig who was studying in Berlin and had maintained contact with Colonel Becker already since 1922 repeatedly drew attention to the fact that experiments were being carroed out in America with centrifugal cast gun barrels. During a visit to the United States in 1930 Colonel Becker (Proving Branch 1--Ballistics and Ammunition) and Lieutenant Colonel Zimmerle (Proving Branch 4--Artillery Equipment) were shown these experiments and the necessary installations. They were very much impressed and recommended that similar experiments should be started in Germany. Initially it was difficult to find an industrial firm willing to undertake such experiments. Both Rheinmetall and Krupp rejected the idea, since they considered it could not prove successful. The firm of Mannesmann, which manufactured cast iron pipes for industrial purposes was also unwilling to undertake experiments with alloy steels. Finally, in 1932-1933, the Bochumer-Verein Combine agreed to initiate experiments along the suggested lines in its research installations. At first attempts were made to produce barrel sections in lengths of two to three meters by the centrifugal casting

125-126 method, the first objective being to find an alloy steel suitable for the process. Carbon steel was found lixk easier to handle than the higher quality steels, but it was just these high-quality alloy steels for which a centrifugal casting method was to be sounght. The correct temperature at which the steel should be poured into the mould had to be determined, and consideration also had to be given to the proper temperature which the mould (Kokille) itself should have. Then the quantity to be used for the casting had to be determined with great precision, followed by a study of the cooling-off processes after the metal entered the mould. The revolving speed of the centrifugal apparatus naturally also was an important factor.

It was realized from the start that a long series of tests would be necessary. However, important results were confidently expected for the manufacture of gun barrels, particularly during war, and therefore a start had to be made at the project.

The short section of gun barrels initially manufactured by the centrifugal casting process were tested to ascertain their resistance to blast effect and the metal density. Here, a very favorable phenomenon was observed: during the centrifugal motion those elements which contributed towards good blast resistance were forced to the xxrfxxxx outside

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126-127 surfaces, while the inner surfaces, which were exposed to attrition in firing, showed only small traces of those elements of the steel material which favored the attrition processes.

However, each new type of alloy used required renewed series of tests, since each material reacted differently during the process.

Particularly serious difficulties were encountered in removing the finished casting from the mould; in which respect the cooling-off process was of particular significance. In numerous cases the castings were so firm in the forms that they had to be drilled out, and in some cases the forms even had to be sacrificed. Tests also revealed that if at all possible the outside surface of the casting should be left infinished, since any finishing processes reduced the stability of the entire barrel. The inside had to be drilled out to the proper bore and the rifling grooves had to be cut. In all cases large pipings were found in the inner parts, which were a regular occurrence and unavoidable in centrifugal casting. The rotating speed naturally played a significant role in the formation of these pipings, but when they were in the parts which had to drilled away anyhow, these pipings were of no importance. These were needed, however, to show how deeply they extended.

The experience thus gained showed that new gun barrel

126-127 constructions would have to be adopted. The liner tube parts provided for in the case of antiaircraft guns were a favorable feature in the centrifugal casting system. An outer finishing was unnecessary, and the entire barrel was af approximately the same thickness throughout its length. In the case of guns not submitted to all too excessive stressesit was found most economical to have the entire gun barrel in one single centrifugal casting, as was planned with the Model 18 light field howitzer. However, the past system of fastening the barrel to the bed with clamps had to be abandoned; a more suitable method was found in fastening the barrels with clips. For antiaircraft guns the barrels could not be in one casting, since the stresses in firing were too great.

In past gun barrel construction it had been necessary to cast a large enough metal block at the roller milland then cut the barrel out of this block . The centrifugal casting method made it possible to do away with these exceedingly difficult and time-consuming processes, which also necessitated large presses and other tooling machinery.

At the start of World War II in 1939, the experiments were not yet concluded, but efforts were being made to bring the project to a satisfactory conclusion and to enter the stage of mass production after tests which had lasted since 1932.

127-128 It was 1942 before the new methods could be authorized for mass production, and from then on complete barrels for the ground artillery and a large percentages of the liner tubes for antiaircraft guns were manufactured by the new processes. It was due to this circumstance alone that Germany was able during the war to produce the large masses of guns required.

Small-bore gun barrels were cast vertically, while horizantal casting was preferred for calibers heavier than 75-mm. The principal firms manufacturing gun barrels by the new method were the Bochumer Verein Combine and the firm of Fischer, in Schaffhausen.

All else that needs to be said concerning gun construction has been said in the previous sections of this study.

In the field of fire control director equipment it has been stated in the previous sections that the Kapa Model designed by Dr. Ingenieur Kuhlenkamp under instructions from Weapons and Equipment Proving Branch 10 was in the testing stage. The object here was to improve on the Model 36 Director which could only determine a straight line flight, and produce equipment which could determine more precisely the movements of a target in curving flightand thereby furnish the precise data factors for the point of missile-target intersection. This improved model was not quite ready for field service

128-129 in 1939 and was only supplied to the troops in 1940.

Large research and development projects were also in process in two other fields which were to prove highly successful at a later stage.

The first of these was the field of radar locating, in which field the firms of Lorenz and Telefunken started work on assigned projects prior to 1937. For antiaircraft artillery purposes the demands made on the instruments under development had to be very high, since they were designed firstly to replace the acoustic instruments currently in use and secondly to furnish the firing data for defense action during conditions of poor visibility and against aircraft operating above a cloud cover or at night. By excluding the sonic speed lag, which had to be taken into consideration in the use of sound locators, radar locating would have made it possible to train searchlights directly at the target and so illuminate it that the personnel handling the fire control director instruments to take their bearings under conditions similar to daylight. Furthermore, a precise knowledge of the distance of aircraft and the direction of their flight would have removed the necessity for barrage fire against unseen targets, defense action which involved the expenditure of enormous quantities of ammunition, frequently without need. Barrel attrition would also be reduced to within tolerable limits.

129-XXM Work on the development of these instruments was vigorously supported by XXXXX Proving Branch 10 and received powerful impetus when it was found in 1939 that the Air Force had also done some preliminary work in this field. The Air Force required instruments of this type for air reconnaissance purposes and to procure data for the compilation of current air situation reports. For these purposes the data procured did not have to be as precise as that required for the antiaircraft artillery, which needed extremely precise data for the directing of gun fire, and inaccuracies even within narrow limites would have been useless for this purpose. The problems involved here showed clearly how harmful it was for antiaircraft artillery that there was not mutual reasearch and development authority but instead that the flying branch of the Air Force had its own development and procuring department in the form of its C-Office The situation therefore now arose in which a decision had to be made as to who was to be responsible for continued research and development in this particular project, since the same industrial concernes had to be used for both purposes. This decision had not been made by the start of World War II in 1939 but it was becoming obvious that the matter had to be clarified. This subject will be dealt with further later in this study.

Snother field had become ripe for research and development in this same period, namely, the field of rocketry. In 1929

129-130 various civilian agencies had carried out tests with rocket propulsion on test sections of the ~~XKtobahnXXsuperXhighXwayX~~ national railways and also with rocket-propelled automobiles. All of the work doen in this field was at the time considered by many as utopian and was rejected. The Weapons and Equipment Proving Department (under General Becker) of the Army Ordnance Office realized that the tests might indicate a means to be used for purposes of national defense and therefore at the end of 1929 concerned itself with these tests. There was complete clarity at the time on the difficulties involved in the problem of rocket propulsion, and it was also perfectly clear that no private concern was in a financial position to solve a problem of such magnitude alone.

Neither the heavy industries nor the universities showed any interest whatever in the problem, so that the Army Ordnance Office itself had to take up the necessary research work, building on the work already done in the field by such pioneers as Winkler, Engel, Nebel and von Braun. Dr. von Braun was engaged for the purpose.

As a start, a special experimental station was established in Kommersdorf, near Zossen, Berlin, for the testing of liquid fuel rockets, and on 21 December 1932 a combustion cutoff in a combustion chamber was attempted for the first time on the test bed there.

130-131 This was followed in 1939 by construction of the first missile "Apparat 1," for which Major Dornberger, together with Dr. von Braun, had done the preparatory work. On 3 October 1934 came the first takeoff of a liquid-fuel rocket, which succeeded beyond all expectations , the missile reaching an altitude of 90,000 meter (roughly 99,000 yards) and achieved a maximum speed of 1,500 meter/second and a firing range of 192 kilometers (roughly 120 miles).

After the Air Force also became interested in this project and decided to make funds available, a start was made in 1936 with the construction of an experimental and testing station at Peenemuende on the Isle of Usedom. The first firing tests after this were carried out on the Greifswalder Oie (islet) and were a miserable failure. Work was continued under great difficulty. Funds were short and the support needed from industries and the various research institutions was given only with reluctance and very sparingly.

Owing to all these circumstances it was still not possibl to foresee in 1939 when this project would be completed, in spite of the great amount of work done on it by Weapons and Equipment Branch 11, specially established for the purpose. The only tangible result achieved was a smokeshell firing frame which was practically completed at the time and was supplied to the troops in 1940.

131-132 So much can be reported here concerning the pioneering work done up to 1939 in the field of rocketry, which was destined later to become of such significant importance to the antiaircraft artillery. Without that pioneering work the possibility to solve the problem of the heavy antiaircraft rocket, which involved not only rocketry but also complicated electronic problems, would have been even more remote at the time than it seemed anyhow. The subject will be further discussed later in this study.

WEAPONS AND EQUIPMENT PROVING BRANCH 10
(AA Equipment of all Types)

As previously related, a special staff, Training Staff 3, (Lehrstab 3) was created in 1930 to handle all antiaircraft artillery problems within the Artillery Inspectorate of the War Ministry. The various Weapons and Equipment Proving Branches continued to handle the technical development projects as in the past. It was only in 1934 that a Special Sub-Section for AA Guns (Sonderreferat fuer Flakgeschuetze) was established within Proving Branch 4 (Artillery Equipment). Until that time the sub-section for heavy artillery weapons and equipment had handled AA guns concurrently with its other missions. The chief of the old sub-section, Major Mertitsch, took over the new Sub-Section for Antiaircraft Artillery, while a

131-132 new officer was assigned to head the sub-section for heavy artillery.

On 1 May 1935 the antiaircraft artillery arm was incorporated with the Air Force, so that the Sub-Section for AAA Development now also came under the Air Force, and Major Mertitsch later became chief of the Weapons and Equipment Proving Branch 10 in the Reich Air Ministry. The various Proving Branches of the Army Ordnance Office released personnel to staff the newly established branch. Proving Branch 4 provided the personnel for the Sub-Section for Heavy AA Guns, and an antiaircraft artillery officer (Dr.Krause) was assigned to head it, since Major Mertitsch had taken over the whole branch. Proving Branch 2 provided the cadre personnel for the subsection handling light AA guns under Captain Stahel. The sub-section for AA searchlight and sound locating instruments, under Major Mattner (ordnance) came from Proving Branch 5. A sub-section was also established for vehicle problems, under Major Walther (Reserve), but was still required to cooperate fully with Proving Branch 6.

Proving Branch 8 also released personnel to furnish a cadre staff for a sub-section for AA rangefinding and fire control director equipment. Initially, this sub-section was under Major Reimann, who was replaced in October 1936 by Captain Deutsch. These two officers both came from the antiaircraft

132-133 artillery arm, and the latter while in officer status had graduated in technology.

Proving Branch 1 continued to handle ammunition and ballistics, and Proving Branch 3 continued to handle preparations for manufacturing. The Air Force only established its own branches for these subjects at a later juncture. It was probably only in 1939 that AF Proving Branch 10 took over these functions, when Colonel Steinkopf-Hartig (Reserve), who at one time had worked in the Army Weapons and Equipment Proving Department, took ofer a newly established Air Force sub-section for ammunition and ballistics, while Count von Bouillon, until then in Army Proving Branch 4, took over the Air Force sub-section handling the technical preparations for manufacturing.

This establishment of a separate department for the development of AA weapons and equipment took place at an unfortunate time, the time of general rearmament, when all regular officers available were required for service with troops. Practically all responsible staff members were not antiaircraft artillery officers, but retired officers recalled for military service. Even the branch chief, Major Mertitsch, had served formerly in the foot ertillery and only after 1918 had commanded a motor-vehicle-carried battery of converted 75-mm AA guns at Jueterbog. As sub-section chief for

135-136 heavy artillery in the Army Ordnance Office Proving Department, and also in the development of AA weapons and equipment he had done excellent work, but he lacked the knowledge and understanding of the fundamental problems of the antiaircraft artillery which was an absolutely essential requirement in the direction of development work in the various individual fields of antiaircraft weapons and equipment. Instead of assigning him to a field unit for a period of two to three years to acquire this basic knowledge, he was retained in the Ordnance Office until 1942, when it was too late for his career.

Colonel Steinkopf-Hartig was also not familiar with the needs of the antiaircraft artillery, and had to rely on the knowledge acquired during his former assignments in the Military Technical Academy and the Artillery Proving Commission, in his new post where he was responsible for ammunition and ballistics. Many of his staff specialists were ordnance officers; these were not from the antiaircraft artillery, however, but had received their specialized training in the subject of ammunition, on which they had to base their work in their new assignments. In the subject of ballistics, Colonel Steinkopf-Hartig was supported by technologists, but their knowledge was also restricted to their experience as reserve officers participating in occasional exercises.

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134-135 In the sub-section for rangefinding and other such instrumentsofficers from the antiaircraft artillery were assigned. Major Heimann had served as an officer in the arm during World War I, in 1914-1918, and therefore was thoroughly conversant with what was needed; his successor, Captain Deutsch, had completed his university studies in technology, which qualified him fully for his mission. But even he had only served as commander of an AA battery, and now was retained by the Personnel Offic in the Technical Office from 1936 to 1943 instead of being afforded an opportunity of gaining new experience at the front, which he could then have exploited in the execution of his mission. However, this necessity was as a rule overlooked by the Personnel Office, which thereby rendered the officers concerned and the cause itself a serious disservice.

The question unavoidable arises here as to where the antiaircraft artillery officers were who had completed their university training at the expense of the State, and why the Personnel Office did not assign them to the posts for which they had received this training. It would have been their duty to exploit their knowledge in these posts, and it was there that they could have and should have made their influence felt to the benefit of their arm in the field of continued development. In view of the small numbers of officer personnel available, it is only natural that every officer was

134-135 needed in the front line units who could be spared for that purpose. However, these officers were not with the troops; instead they spent their time on the General Staff.

It would be hard to find a more flagrant expression of an utter disregard for technology than was evidenced in this second-rate filling of technical posts so far as basic technological qualifications were concerned. Instead of making the most experienced and best qualified officers of the antiaircraft artillery arm available for the further development and improvement of the arm, officers without any experience in the arm were assigned to this mission.

The question is also unavoidable as to why, in contrast with the troops, the antiaircraft artillery development activities were not assigned completely under the Air Force (the C-Office). There were probably a number of reasons for this. In the first place, all preparatory work in the past had been handled by the Weapons and Equipment Proving Branches of the Army Ordnance Office. Secondly, General Ruedel, Inspector of the Antiaircraft Artillery, and General Becker, Chief of the Weapons and Equipment Department of the Army Ordnance Office, were old acquaintances and firm friends, and it was felt quite generally that the continued development of antiaircraft artillery equipment could be handled better by the old-established Proving Branches than by a branch

135-136 to be newly established under the Air Force C-Office. Furthermore, the entire industry, including the concerns participating in the development of antiaircraft artillery items of equipment, were engaged primarily on projects for the Army, and any measures disrupting the systems of cooperation which had developed in the past undoubtedly would have resulted in unnecessary interferences in continued work. The close cooperation which existed between the individual subsections ~~on the one hand~~ and the Proving Branches on the one hand with the other Proving Branches on the other hand also prodúced favorable results later on.

Procurement also remained under the Army Procurement Office. Here again the same firms participated in supplying the needs of the Army and of the antiaircraft artillery, and the system of channeling all contracts through one single authority could undoubtedly serve in many cases to smooth out friction in the incipient stages. Difficulties which nevertheless did arise later during the war will be discussed later. Such difficulties and complications arose mainly in areas where the needs of the antiaircraft artillery encroached on the manufacturing needs of the flying branch of the Air Force, namely in such fields as rocketry and rangefinding and similar instruments and from the fact that the needs of the antiaircraft artillery had to be met from the raw

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136-137 materials allocated to the Air Force and the fact that the quantities needed frequently were not transferred in time to the Army Procurement Office. This was particularly the case when there was a sudden ~~xxxxx~~ and unforeseen shortage of raw meterials. The difficulties resulting from these circumstances could have been avoided if there had been a combined military technical development and procurement office handling the requirements of all three military branches, the Army, the Navy, and the Air Force. This subject will be discussed later with due reference to the ministry under Todt and later under Speer.

Mention must also be made here of the excellent cooperation between the Antiaircraft Artillery Inspectorate and Weapons and Equipment Proving Branch 10. This cooperation certainly made it possible to surmount many of the difficulties discussed above, which were due to ignorance of the staff personnel in the matters for which they were responsible. I am nevertheless firmly convinced that , just as is the case with the officer personnel assigned as specialists to the Inspectorate, officers assigned to technical staffs must have actual combat experience in the arm they are to represent in order to be able to really exploit all opportunities for the further development and improvement of that arm.

When the German Air Force was first established as a

136-137 separate branch of the armed forces it also took up the question of technical training for officers. In doing so it did not insist on a full university course or a full course at some similar institution. This was probably because of the disappointing experience in the past with officers who had completed their full university training in technological subjects.

For the above reasons the Air Force established an Air Technical Academy adjacent to the Air Command and General Staff School (Luftkriegsakademie) at Gatow, Berlin. This new academy (~~Lufttechnische Akademie~~) was headed by General Kar-lowski, a former chief in the Weapons and Equipment Proving Department. However, ~~xxxx~~ of the officers selected for General Staff Corps training on the basis of examinations too few applied for technical training even in this eminently technical branch of the military establishment, where technology plays such a decisively important role, particularly in the flying branch, but also in the antiaircraft artillery branch. Practically all of these candidates preferred tactical training because of the raised status it was generally considered to confer. For this reason, specific officers were later detached for technical training, whose background (matriculation exam, rating by superior officers in front units,etc) seemed to indicate that they were interested in technical

137-138 subjects.

The first course, which was to last three years, started on 1 November 1935. The subjects taught were: mathematics, mechanics, chemistry, physics, electro-technology, communications technology, air technology, automotives, raw materials research, ballistics. A separate institute was established for each subject and equipped with valuable installations. The start thus appeared to hold out good prospects of success.

As a result of remonstrances by the General Staff, the duration of training was reduced by one year a year after the start, and another six months later the course, originally planned to last three years, was closed after a duration of only eighteen months.

When the second course started on 1 December 1936, the duration was radically reduced to a duration of only one year, which naturally made thorough training impossible.

On 1 January 1938 the separate program of technical courses was terminated, and technical subjects were only treated in lectures forming part of the curriculum of the Air Force Academy. General Karlowski departed in the spring of 1939, which practically put a complete end to technical training. Once again technology had been sacrificed to tactics.

Later in the war the inescapable need of an Air Fo ce Technological Academy became apparent and it was reestablished

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138-139 as will evolve later in this study.

After first experience with officers who had completed a full course of university studies in technological subjects, the Army also decided to find a different solution. University training in the separate subjects provided knowledge which was not of great importance for an officer in his career. The idea was to establish a separate military technical faculty within the Technical College in Berlin, where it would be easier to supervise the progress of the officers in their studies. Under this arrangement it was thought that there would no longer be the possibility of an officer realizing only after three semesters that he could not meet the high standards applied in university studies and deciding to return to service with troops. The time thus lost was not only harmful to the career of the officer concerned but was also a disadvantage to the whole arm; furthermore the funds expended by the State for the purpose were wasted.

The curriculum at the new military-technological faculty was to be arranged to meet the military requirements, and it would be possible at any time to withdraw officers who proved unsuitable for further studies.

The military-technical faculty was established at Berlin/Grunewald at the end of 1937 but the start of the

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139-140 war put a premature end to this project.

After the technological courses at the Air Force Technological Academy had ceased, the valuable laboratories which the Air Force had installed for the purpose at Gatow were no longer needed and were therefore used after the beginning of the war for equipment reserach and development purposes. The fact merits mention here that the professors concerned, and in particular Professor Schardin, managed to make very good use of these installations, although that use was different from that for which they were originally intended.

6. The Antiaircraft Artillery Development Program of 6 December 1932 and the Stage Reached by the Start of World War II in 1939. At the start of the war there were in existence 115 antiaircraft artillery battalions activated under peacetime conditions. The heavy battalions had 88-mm guns Models 18 and 36, and a few of them had 105-mm guns. All XXX XXXXXXXXXXXXXXXXXXXX batteries had Fire Control Director equipment Model 36 and also each had an auxiliary fire control director. For self-defense against low-altitude air attack, each battery also had two 20-mm AA guns Model 30.

In addition to the above, each heavy battalion had two batteries of 20-mm AA guns, the battery organized in four platoons of each three guns plus four 60-centimeter searchlights.

139-140 Besides the heavy battalions just mentioned there were also in existence light antiaircraft artillery battalions, the most of them having each two batteries with the same composition as those assigned to the heavy battalions, plus a 37-mm battery. These latter had 37-mm guns Model 18 or 36, but had only three platoons of each three guns and three 60-centimeter searchlights.

The 150-centimeter AA searchlights were organized in AA searchlight battalions, each having three batteries of three platoons with each three searchlights. Ring-shaped sound locators were assigned to two out of every three platoons, because the platoon holding the inner perimeter had no such equipment.

All items needed to equip the units listed above had been produced, plus almost adequate stocks for the reserve units for the immediate activation of which plans provided.

Ready for the field in 1939 were

2,600 heavy AA guns
6,700 light AA guns
1,700 150-centimeter AA searchlights
1,300 60-centimeter searchlights.

This must be considered a remarkable achievement when it is taken into consideration that the AA arm had been built up from scratch since 1932, and thus within seven years.

140-141 In comparing the equipment available at the start of the war in 1939, as listed above, with the figures of the AAA Development Program established on 6 December 1932 (Appendix 2) the following becomes evident:

Ad C.

a. Weapons for Defense against Low-altitude Attack. The specified range of effective fire for machine guns, 880 yards, was not fully achieved. However, it can be considered that this standard was too high, since these weapons fired with ground observation and tracer ammunition. Since visual observation without aids is only possible at a maximum range of 660 yards, an effective firing range of only 660 yards should have been specified.

Ad C.

b. Special Weapons for Defense against Low-Altitude Air Attack. In general the 20-mm weapons probably met the specified requirements, although the specifications were not fully met in point of rate of fire and overall weight. The specifications here were 300-500 rounds per minute; total weight of the weapon 440 pounds. The results achieved were: rate of fire, theoretical 300, in practice 190 rounds per minute; overall weight of the weapon in firing position 990 pounds.

The specifications for a 37-mm weapons were also met

141-142 on the whole as stated in the program. The specified missile speed of 3,300 yards in a maximum of 7 seconds was not achieved. Instead the missile speed was only roughly 3,000 yards (2,700 meters) in 7 seconds. Traverse speed was also not as specified being only 10° per revolution of the handwheel.

Ad C.

c. AA Guns for Fire against Reconnaissance, Observation, and Bomber Aircraft. The 88-mm AA gun, Model 36, on the whole met the requirements stated in the program.

Ad. C.

d. (1) Fire Control Director for Medium Caliber AA Guns. The models developed did not meet the specified requirements. The sighting device designed for the 20-mm AA gun was also suitable for use with the 37-mm model. On the whole the computor instrument assigned with the gun also met the stated specifications. The 37-mm AA gun was still light and easily maneuverable, and it was thought better not to decrease these advantages by coupling the weapon with a separate data computor and the gear to transmit the firing data to the guns.

Ad C

d. (2) Fire Control Director Equipment fo Heavy Caliber AA Guns. Model 36 Fire Control Director met the requirements stated in the program. The auxiliary fire control director had been planned somewhat differently from the final actual

142-143 model. However, the requirements stated in the program were so farreaching that it can not be said whether the performances of this equipment, Model 35, could not be considered as complying with the specifications.

Plans to separate the rangefinder from the fire control director were dropped after negotiations between the Inspectorate and Proving Branch 10, since the solution combining these two elements embodied a number of advantages.

Ad C.

e. Searchlights and Sound Locators. One notable point in the specifications for searchlights was that the sound locator was to have an operating range of twelve miles. This is a very excessive requirement, since only gigantic instruments which would no longer have been ~~mmkx~~ capable of mobility could have met it.

The subject discussed under this heading includes firing by data coming from sound locators and fire control director equipment, a method not taught or exercised under peacetime conditions. This problem only became realistic in 1940, when it was found that idea the formulated in 1932 had not been as unreasonable as had appeared at the time. However, the fact remains that even in 1940 nobody had the slightest idea how to effectuate these thoughts, and impossible suggestions and ideas were then thoroughly examined and tested.

143-144 In principle, this was a mission which the schools should have taken up prior to the war, and I am unaware of the reasons why they did not do so in spite of the requirement stated in 1932 and why the Inspectorate did not follow the matter up.

The stated requirement for searchlights to be trained on the target by means of heat waves , etc., stemmed probably from thoughts of ultrared rays. This requirement was stated on the basis of certain research work which had been done but which had only produced equipment using these means over very short distances with success. The solution desired was not found.

Ad C

f. Other Means of Defense. In the field of balloon and kite air barrages, altitudes of 5,500 yards were achieved only with kites. Using balloons the highest altitude reached was 3,850 yards.

The stated requirement for barrage fire rockets at that time was far ahead of developments, since research had just commenced in this field, and there could have been no thought of developing equipment for the use of barrage rockets. This case shows how harmful such exaggerated requirements can be, since practically nothing whatever was done in the matter; it was simply ignored and neither the Technical Office nor the Arms Inspectorate, which had

144-145 assigned the development mission, ~~nor the Inspectorate~~ troubled to follow the matter up and see how the project was progressing. It must be mentioned in this respect, however, that the Dornier Works in 1939 had completed the development of a rocket launcher which could have been used as an air barrage rocket firer for air defense purposes by filling the rockets with explosives, etc., instead of with smoke chemicals. It is unknown to me why such problems were apparently simply dropped. In any case, the fact that the requirements was stated at a time when the whole complex of these problems was still in the incipient stages of research did not serve to promote solution of the problem.

Ad C

g. Receivers and Data Analyzing Instruments. Much work was done and much was achieved in this field. The requirements stated in the program were met.

Ad C

g. The Testing of Personnel handling Rangefinders and Optical Instruments in the Garrisons. The stated requirements in this field were met.

Ad C

g. (2) Photographic Recordings during Firing and during Special tests of the Fire Control Director Equipment. Measures were being taken and in some cases had already been taken to meet these requirements. The stated requirement for simulation

145 actual war targets by means of unmanned remote control guided target aircraft at that time was a dream wish which was not met. Here again, the stated requirement was far ahead of the feasability of its being met, since the reasearch work involved had probably just started prior to 1932.

Ad D. Priority Sequence. Apart from the requirement for air barrage rife rockets, which was placed in category a: urgent, the requirements were met.

As an overall status assessment it can thus be said that on the whole the requirements stated by the Inspectorate and by the General Staff were fully met insofar as this was possible within the scope of the ateg of technological development at the time.

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CHAPTER 4

THE GERMAN ANTIAIRCRAFT ARTILLERY IN WORLD WAR II
1939-1945

1. German Antiaircraft Artillery Weapons During World War II.

On 13 December 1938 Goering had established a delivery plan for antiaircraft artillery equipment covering the years 1939-1942. The schedules contained in that plan provided for the following deliveries to be made:

20-mm AA guns Model 30	982 monthly (raised from 400 monthly) up to a total of 30,000 guns.
37-mm AA guns Model 36	109 monthly (raised from 50 monthly) up to a total of 5,000 guns.
88-mm AA guns Model 36	155 monthly (raised from 20 monthly) up to a total of 8,200 guns
128-mm AA guns Model 40	100 guns to be manufactured in a single production serie[s] as a start
105-mm AA guns Model 38	152 monthly (raised from 20 monthly)up to a total of 2,000 guns.

Very optimistic opinions were held on the effectiveness of the antiaircraft artillery and found expression in various ways. Thus, Goering had gone so far as to say: "You may call Maier if a single enemy bomber should manage to drop bombs on the Rhine-Ruhr region " /"Maier" is a German surname even far more common than the surname "Smith" in English and is

147 quite generally used to denote complete ignorance of a subject under discussion. There are various spellings: Maier, Mayer, Meier, Meyer, Note by Translator]. However, it was not only Goering and laymen on the subject who held such exaggerated views. On the basis of the results obtained in firing tests at the various firing ranges it was quite generally considered justifiable to assume an average of 47 rounds to bring down an aircraft, which was to prove a fateful error. In the first place target simulation left much to be wished for and secondly the conditions at firing ranges were very different from those experienced later under actual war conditions. In firing tests the target was a towed plane, and towing seriously reduced speed and maneuverability. Furthermore, the flight of the target was adapted to the training status of the troops being tested, and the target altitudes rarely corresponded to those at which aircraft would operate under war conditions. During the war light AA weapons very often had to fire at targets flying at the extreme limit of or even beyond their effective range. In addition the aircraft used to simulate the target in tests were usually outdated models which could not achieve the performances of modern aircraft.

The outcome of all this was that those responsible lulled themselves into a false feeling of security. This, in turn, resulted in the establishment of cordon of antiaircraft

147-148 artillery positions following the general line of the Westwall which was then called an "insurmountable AAA zone." It was assumed that the AA forces within this zone would deny enemy aircraft passage over the zone and thus protect the homeland completely against enemy air penetrations.

In spite of the general spirit of optimism, there does some to have been some doubt, since measures were introduced establishing local air raid protection organizations.

The truth of the matter was no doubt that false information was intentionally disseminated among the general public and the higher level authorities of the National Socialist Party, who accepted this information as Gospel truth, a course of action which was unpardonable and could never have been expected.

At the start of World War II there were in the West Wall Air Defense Zone a total of 197 battery positions for 88-mm guns and 48 for automatic (20-mm ans 37-mm) AA weapons, a gun strength which in any case would have been inadequate to provide absolute protection against air attack.

Since the forces available were numerically inadequate to protect all targets which it was thought had to be protected, the light AA weapons were committed individually in direct contradiction of the tactical principles evolved during peace. In like manner the searchlight support

148-149 provided was very often totally inadequate.

From all of the above it is obvious to what small extent a realistic understanding of the antaircraft artillery problems and capabilities had become general knowledge, even in the higher command levels of the aitiaircraft artillery itself. Even as late as in 1940 there were still responsible commands which believed that they had adequate antiaircraft artillery strengths to fully protect the areas for which they were responsible, for which reason they declined the reinforcements offered to them in the firm conviction that they could effectively repel with the weapons already available any air attack against their territory. These circles were destined to be bitterly disappointed.

In 1939 defense measures had to be based on the following assumed aircraft speeds: reconnaissance planes, 290 miles; bombers, approximately 180 miles. The striking range of fighter aircraft was approximately 210 miles; that of bombers approximately 900 miles. Maximum altitudes were: for fighters 26,000 feet; for bombers carrying a bombload 16,500 feet. According to ruling views among German authorities on air warfare, it was not to be expected within the foreseeable future that aimed bombing would be possible from altitudes above roughly 13,000 feet. Blind

149-150 bombing, and thus also night attacks, on any appreciable scale were also considered impossible.

It was on these premises that the German antiaircraft artillery arm had based its development programs, and viewed in this light in can be considered that the technical performances of the equipment available were adequate.

LIGHT ANTIAIRCRAFT ARTILLERY

Guns. Peacetime developments have been dealt with in the preceding chapters of this study and it evolved during the account given that Germany at the start of World War II in 1939 had available for defense against low-altitude attack

a 20-mm AA gun and
a 37-mm AA gun.

Shortly prior to the start of the war the troops had received an improved 20-mm Model 38 AA gun. This new weapon was a recoilloader with a centrali breechlocking mechanism. It had a movement in elevation of -20° to +90°. Its traverse speed had been improved to 10° per revolution of the handwheel and using the accelerated setting even to 30°. The possible elevation adjustment was 4°, and using the accelerated gear 12°. A gun shield was provided, and the weapon could be manhauled on Special Type Trailer Model 51)Photo 79). Because it was readily dismantled and because of its movement of elevation ranging from -20° the weapon was ideal

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pp 184-185 not used

150-151 for use in roof positions. Later it was also mounted on rail-cars and in permanent emplacements (photo 80). At the front it was used on a self-propelled mount from 1942 on (Photo 81).

A point which merits special mention is that the rate of fire of the new gun had been increased considerably ; the theoretical rate of fire was 450 rounds per minute and in acutal firing under battle conditions it fired well over 220 rounds per minute. Because it used the already existing types of ammunition its ballistic properties and its effective range remained unchanged, but its weight was smaller than that of the old gun (20-mm AA gun Model 30). In firing position the new weapon weighed approximately 920 pounds (420 kilograms); its riding weight was approximately 1,600 pounds (740 kilograms); the weight of the shield was approximately 260 pounds (120 kilograms). The new weapon had a Model 38 AA sighting or aiming device of simplified construction which allowed an increased lead angle of plus-minus 22°.

In spite of its increased rate of fire no doubts were entertained that even this new gun would not be able to place more than one projectile on target and that one 20-mm missile was inadequate to disable an aircraft or to destroy it. For this reason attempts were made to increase the effectiveness of 20-mm fire by four-barrel mounts for the new Model 38 20-mm AAA gun barrels. These four-barrel models were used

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150-151 first by the Navy for ship armament and were supplied to troops in the field already in 1941 (Photo 82).

The four-barrel mount allowed a movement in elevation of from -10° to +100° and thus could be swung over the upright. The fire performance was good, giving 800 rounds per minute from all four barrels together, and the hope was justifiable that under favorable circumstances two missiles would strike the target simultaneously, which naturally would greatly increase the effectiveness. One revolution of the handwheel changed the elevation by 4° or, using the accelerated gear, by 12°. The traverse speed was 7.5° per revolution of the handwheel, or 22.5° with the accelerated gear. The mounts were motor-towed on Special Trailer Type 52. They could be used in permanent emplacements, on railcars, or on self-propelled mounts (Photo 83). A shield was naturally also provided. The stripped weight in firing position was approximately x,xxx 3,330 pounds (1,514 kilograms); the riding weight, with special trailer, was approximately 4,866 pounds (2212 kilograms).

Using tracer ammunition, the four-barrel guns also had an impact on enemy morale and were greatly feared by airmen in low-altitude attacks and particularly in dive-bombing attacks. Targets defended by four-barrel guns rarely came under dive-attack, once the enemy had detected the presence of

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151-152 these weapons.

It is hard to understand why the excellent effectiveness of these four-barrel guns was not realized and fully exploited from the very outset. During training, and even at the AAA School, instructions were frequently given to use only two barrels simultaneously in order to continue sustained fire with the other two barrels while changing ammunition magazines. It was naturally possible to use two barrels separately, particularly when one of the barrels failed because of loading interferences. The standing rule should have been, however, to bring the full weight of fire of which the four-barrel gun was capable to bear particularly in the first burst of fire against an aircraft. It is an actual fact that it was only after very strict orders had been issued to this effect that the troops began to realize this. Here was another case where it proved so very difficult to uproot and change what the troops had learned in their training.

Unfortunately, the old practice again came into evidence of delivering the first few rounds as adjustment fire. That this practice was impossible in antiaircraft fire everybody admitted more or leass readily, but unfortunately gun crews fell into the same old error time and again. The practice was particularly intolerable in the case of automatic weapons with their short range of effective fire, since it involved the loss of the

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152-153 the critical moment during which really effective fire could be delivered against the target. It was in this respect that certain faulty practices of peacetime training proved harmful. The delivery of single rounds had not only not been dis- but had actually been encouraged, usually to economize in ammunition. In actual fact that fundamental principle in antiaircraft action that the full force of the weapon must strike the enemy destructively in the first burst of fire applied even more in the case of light automatic weapons than in that of other antiaircraft weapons. If the first blast failed to down the enemy it had simply to be admitted that preparation had been inadequate and that this was the reason why the fire had failed to reach the target.

In the hands of a really able gunner the 4-barrel gun was really a weapon to be feared and was therefore called the "Hell of Antiaircraft Fire" by enemy airmen.

Four-barrel guns were usually in batteries of 20-mm guns, which also had single-barrel weapons. Acapable battery commander thus was able to make the most effective use possible of this weapon by assigning his best gunners to man it. Membership in a 4-barrel gun crew shouls have been considered a sign of special recognition within the battery, and any member moved from a 4-barrel to a single-barrel gun should have been made to feel that he was being down-graded.

153-154 Regarded in this light, the weapon undoubtedly would have produced even better results. Unfortunately a proper understanding for such problems was lacking, and the regulations also failed to give adequate recognition in this respect, since they were based on the use of twin-barrel guns.

Finally, in 1943-1944 it was realized that armored divisions in addition to their assigned antiaircraft units must also be assigned antitank units. However, the units assigned for these purposes were not given a special type mount, an indispensable requirement for AA guns. Instead their guns were mounted on the chassis of Panzer IV Model tanks. These vehicles were constructed specifically for the tank arm but were no longer adequate for their purposes, and for this reason the chassis was given a 4-barrel 20-mm gun. This was a very unsatisfactory solution, since the finished vehicles had the silhouette of a furnitur removal truck with its almost vertical sides and was extremely vulnerable to gunfire. When going into action the sides and rear flaps had to be let down so that the gun and the crew member were completely exposed to fire on a high platform. The first of these antitank models reached the front in September 1943 and a total of 150 were delivered by April 1944 (Photo 84).

During 1944 a suitable solution was found for the

194 AA units assigned to tank divisions for anti-tank defense, and the units were furnished better mounts after the defects of the first solution had become evident and the tank arm also had admitted the necessity to find a proper solution. The new mount, designated the Wirbelwind (Whirlwind) was a light AA type vehicle, with the 4-barrel 20-mm Model 38 gun mounted forward (Photo 85).

Mountain and parachute troops required a lighter 20-mm AA gun, and a ~~suitable~~ weapon for these purposes was constructed in 1940/41. This was the Model 239 gun, a blowback operated weapon with a rigid bolt lock. The mount was of light metal and was dismountable in small parts. However, the weapon did not prove suitable; there were numerous firing interferences and breakages, so that even the 25 already manufactured in the zero series were scrapped.

In contrast, a suitable mount for the 20-mm Model 38 automatic gun was developed for the mountain and parachute troops in 1942 and introduced for field use under the designation of a 20-mm mountain gun, Model 38, in 1942 (Photo 86). The weapon itself was the 20-mm AA gun Model 38 without any changes on a special type guncarriage of stamped sheet metal. It had a permanently mounted shield. Its special exterior features were its tripod mount with removable wheels for transportation. In ground combat it could be

154-155 remain on its wheels. By mounting a tailwheel, for which purpose the inflated wheel of the airdrop container could be used, it could be manhauled easily. The individual loads into which the weapons could be dismantled by hand weighed 88 pounds each, so that it could be transported by carriers or pack animals; it could also be towed by motor vehicle or by a horse, and could also be permanently emplaced or placed on a self-propelled mount. The stripped weight of the weapon in firing position, including the shield, was roughly 700 pounds (315 kilograms); the riding weight roughly 830 pounds (376 kilograms). Intended for use in mountainous terrain, it had a movement in elevation of -20° to +50°, and was equipped with an AA sight Model 40 plus a Model 21 linear sight, and a ground telescopic sight with a magnifying powere of 3x8 for action against ground targets. Its rate of fire and ballistic properties corresponded to those of the 20-mm AA gun Model 38, since it used the same ammunition.

This weapon proved highly satisfactory in field service but was produced in only small numbers as a special weapon for parachute troops. In August 1944 there were only 43 of these guns in existence, and in February 1945 180.

As related in previous chapters of this study, the 37.5-mm caliber had been badly neglected during peacetime developments. Even after the start of the war in 1939 there was

155-156 some reluctance to approach the task of improving the existing weapons with this caliber. The longer the war drew on, however, the more obvious it became that a weapon in this class was an indispensable necessity, for which reason the firms of Krupp and Rheinmetall were requested in 1941 to design a new model. For reasons of ammunition procurement it was necessary to adhere to the ballistic performances of the existing 37-mm model in specifying the requirements for the new weapon. Other stated requirements were improvements to exclude the functional interruptions in the former weapon and to secure a considerably improved rate of fire. The construction and manufacturing plans were to be such that the weapon, or at least the individual parts, could be manufactured in small factories and that the output could be increased to 3,000 per month.

After numerous failures the firms of Krupp and Rheinmetall early in 1942 finally delivered test models. Krupp's model was found to be the better of the two and in order to avoid any further loss of time after having delayed for so long, the Ministry made the necessary preparations for mass production by the firm of Duerrkop without waiting for the final test results. The firm of Duerrkop thereupon drew up the necessary blueprints for mass production and while doing so modified certain parts for which special machine tools

156-157 would otherwise have been needed.

While these preparations were proceeding, the firm of Rheinmetall produced a new model of the 37-mm gun of stamped sheet metal construction, based on the principles of and experience with the 20-mm mountain gun discussed previously. This new model was submitted for testing while the Krupp-Duerrkop model was still under trial.

In continued tests, the Krupp model had shown a number of defects in the functioning of the gun, and a particularly serious point was that the guncarriage proved too unstable for the stresses and strains of protracted use. Guncarriage fractures occurred time and again, and when one part was reinforced the next firing test showed another part to be too weak.

In contrast, the newly submitted Rheinmetall model showed good functional performances from the start and also had no weak points in the guncarriage.

In addition to the above difficulties, the responsible military authority for this development project, Branch E (AAA) of the Office of the Chief of Air Force Special Supply and Procurement Service, were fully aware that the two guns under trial were the first two test pieces, on which the producing firms had expended every effort, and that further setbacks must be expected once large-scale production commenced.

156-157 However, time was pressing, since each day more work was being done on preparations for the mass production of the Krupp-Duerkopp gun and adaptation to some other model would have been the more difficult the later it came. For this reason the Development Branch in September 1942 recommended that manufacturing preparations for the Krupp-Duerrkop model should be halted immediately and provisions made for later mass production of the Rheinmetall gun. This recommendation had the effect of a bombshell in Speer's Ministry, particularly on Department Chief (Hauptdienstleiter) Saur. He demanded a decision within 24 hours whether preparations were to proceed for the Krupp or for the Rheinmetall model, and appointed a special examining commission for the purpose. Since the members of this commission because of manufacturing considerations supported the views of the military authority, preparations for manufacture of the Krupp model, which were already 20 percent completed, were halted. The action of the Ministry in taking premature measures on its own initiative without first awaiting the deceision of the military authorities (the AAA Inspectorate and Branch E (AAA) of the AF Special Supply and Procurement Office) produced dire results.

The military authority responsible for the development project demanded, however, that the preparations for mass production should only proceed so far that all machinery which

157-158 was not suitable for use in the manufacture of both models could be procured at a later stage. Saur categorically rejected this and ordered that all arrangements were to be adapted to manufacture of the Rheinmetall modelimmediately, at the same time stipulating the deadlines for delivery. All objections against this action were simply disregarded, and no heed was given to communications drawing attention to the setbacks which might occur when the model went into mass production.

Action of this kind was contrary to all past experience and was therefore not approved by the responsible military-technical authority. However, the powers of the National Socialist Party organizations and of Speer's Ministry were greater, so that the industrial concerns were obligated to insure a monthly output of 1,000 guns by the end of 1943 increasing to a monthly output of 2000 by autumn ~~of the same year~~ 1944, a new gun for which the final manufacturing blueprints had not even been completed as yet.

As was to be expected, production of the 37-mm AA gun, Model 43, failed to function according to plans. After an initial delay of two months, manufacturing started finally in July 1943. What was to have particularly harmful effects now was the fact that Speer's Ministry had given orders that manufacture of the 37-mm AA gun Model 36 was to ~~commence simulatneaously with that of the Model 43 and was to~~

p. 197 not used

15 8-159 be halted when Model 43 went into production, the last guns of this type to come from the factories by the end of 1944. In February 1944 this order was revokedand production of at least 180 Model 36 37-mm AA guns per month continued.

Instead of the 1,000 guns of the new type (37-mm AA, Model 43) which the industries had been compelled to undertake to deliver by January 1944, only eleven were delivered out of the already radically reduced ~~reduced~~ requirement for sixty. Speer's Ministry was alone responsible for this production failure, but tried to shift the blame to the military authorities.

The 37-mm AA gun Model 43 was a blowback loader with rigid locked bolt and with an ammunition feeder attached to the guncarriage. Its rate of fire was 200 rounds per minute; it weighed 2,750 pounds as it came from the factory and 3,300 in the field; the manpower expended in its manufacture totalled 1,000 manpower-hours. The comparative figures for the old Model 36 37-mm AA gun were:weight in the field 11,550 pounds,and thus 3.5 times that of the new model; manufacturing time 4,320 manpower-hours, and thus 4.3 times that of the new model. In addition the firing height of the new was lower than that of the old model. The new gun could be permanently emplaced, used on a self-propelled mount, towed on a special type

158-159 trailer (Photos 87-88). As was the case with the four-barrel 20-mm guns, the new 37-mm gun was also used on the Panther IV IV chassis from March 1944 on. Twenty of the guns thus mounted reached the front line forces (Photo 89).

Since 1942 Model 36 37-mm AA guns had been mounted on 8-ton tractor chassis for use in the field and these were delivered continuously to the troops right up to the end of the war because the output of the new Model 43 gun was too small (Photo 90).

Before the end of 1943 research and development contracts were awarded for a twin-barrel mount for 37-mm guns, for which delivery dates were to be established even before the designing stage was over, which serves to show how urgently the need was felt for the so long neglected 37-mm weapon. The delivery deadlines set by Speer's Ministry called for five to be delivered in March 1944, a monthly output from then to June 1944 of 20, increasing by the end of 1944 to a monthly output of 150 and from April 1945 to a monthly output of 500 of the twin-barrel 37-mm AA gun Model 43. However, these deadlines were completely illusory, since it was not even known at the time whether the twin-barrel mounts designed would meet the requirements of the troops in the field. Consideration was even given to the construction of four-barrel mounts for the

159-180 four-barrel mounts for the Model 43 37-mm AA gun, but both the Military-Technical Office and the Inspectorate rejected these proposals. The weight of the four-barrel gun would have approximated that of the 88-mm AA gun Model 36, and this was considered unjustifiable for an automatic weapon with a probable effective range of only just over 5,000 yards.

The stripped weight of the twin-barrel 37-mm AA gun Model 43 in firing position was 5,500 pounds; its riding weight was approximately 10.600 pounds. The new guns used the old ammunition of the 37-mm AA gun Model 36, for which reason their ballistic performances were also the same. (Photo 91).

In November 1942, the Navy gave out contracts for the development of a 30-mm automatic gun, and the flying branch of the Air Force also called for a similar weapon to be mounted in aircraft. Both the AAA Inspectorate and Branch E (AAA), Special Supply and Procurement Service, considered development of a weapon with a caliber between the existing 20-mm and 37-mm calibers unjustifiable and therefore rejected such proposals.

The specifications in the contracts awarded by the Navy to the firms of Rheinmetall and Bruenner Works called for a double-barrel AA gun with a muzzle velocity of 1,000 meter/secondand a 400-rounds-per-minute rate of fire. The gun was to fire

160-161 a mine grenade with an explosive charge weighing 2.277 ounces (90 grams). At the end of the war 100 of these new weapons were under construction in the Bruenner Works, which were to be mounted on submarines. The war ended before these weapons were used in the field, but tests had shown that the new 30-mm gun could be fitted into the mount in use for the 20-mm AA gun Model 38.

At the turn of the year 1942-1943 Speer's Ministry appointed Armament Commissions (Waffenkommissionen) under "Managing Engineers (Betriebsingenieure)" to coordinate the numerous requests of the Army, Navy, and Air Force and also to insure the most rational exploitation possible of the designer personnel of all firms. Here again the lack of a uniform military-technical control had become clearly evident Each of the three military services, plus the SS, went its own way, and this gave Speer's Ministry the opportunity to interject itself into a mission outside its real sphere of authority. Things had come to such a pass that even the firms complained to the various military-technical offices concerning the parallel developments projects they were required to carry out for various departments, the SS and the Navy even requiring the firms to maintain secrecy on their development projects towards the Army and the Air Force. This was grist to the mill of Speer's Ministry, which was

161 thus enabled to seize control in the field of weapons and equipment development. It is necessary to emphasize here, however, that I experienced excellent cooperation on the part of the two "managing engineers" appointed for antiaircraft artillery weapons and equipment development: Certified (Diplom) Engineer Weissenborn for heavy AA weapons, and Engineer Heynen for automatic AA weapons. Before accepting his appointment, the latter discussed matters with me personally and we exchanged assurances of mutual cooperation and frank discussion of all problems. Only then did he agree to accept his appointment and I can only say here that if this attitude had been more general in the Ministry, it could have done much really useful work. Unfortunately, this was not the case, and the reverse must be said of many of the personnel, particularly the engineering personnel, involved.

The coordination of efforts thus established made it possible to prove to the Navy that its opinion that it could not use the 37-mm AA gun Model 43 for submarine armament was unfounded. The contention of the Navy that the external ballistic properties of the 37-mm AA gun performances did not completely meet requirements had to be admitted. However, at the time when the development contracts were awarded it had been stipulated, on demand by Speer's Ministry and by the Inspectorate, that the new weapon was to use the same

161-162 ammunition as the former model, and this had automatically fixed its ballistic performances. For this reason development contracts had been given out already in December 1943 for a 37-mm AA gun with a muzzle velocity of 1,000 meter/second and a rate of fire of 500 rounds per minute. Unfortunately, this project was not awarded a high priority as urgent, so that it made only slow progress. Designing had hardly gone beyond the initial stages by the time the war ended.

Tests with 37-mm AA gun barrels had shown that chromium plating tripled their useful life, for which reason it had been recommended in August 1943 that the barrels of all light AA weapons should be chromium plated. However, the installations available for the purpose could handle only 1,000 barrels monthly and it was only in April 1944 that a new installation was placed in operation. Another three such installations would have been necessary to meet all requirements. Here, again, however, approval could not be obtained from Speer's Ministry, so that most of the barrels remained without chromium plating.

As early as in 1938 work had commenced on the development of a 50-mm automatic gun. This foresight made it possible to place a few trial batteries of 50-mm AA guns Model 41 in the field already in 1941. This gun was a blow-back operated weapon with a protecting shield and could be used

162-163 on a self-propelled mount, in permanent emplacements, or motor towed on Special Type Trailer 204, and was used in all three variants. (photos 92-94). Its movement in elevation was from -10° to +90° and its muzzle velocity 840 meter/second. It had two traversing gears, one giving it a traversing speed of 2° the other of 8° per revolution of the handwheel; for elevation it had four gears giving it elevation adjustment speeds of 1°, 2°, 4°, and 8°. The rate of fire was 130 rounds per minute, which was quite a performance for those times with a caliber of this size. Its stated range of effective fire was 3,300 yards; its maximum firing altitude was 30,900 feet, its maximum firing range 13,640 yards. Stripped weight in firing position was approximately 6,820 pounds (3,100 kilograms); riding weight approximately 12,600 pounds (5,720 kilograms).

The new weapons was to be used in the same way as the existing 20-mm and 37-mm weapons, and had the same aiming equipment. Because of its longer firing range, however, the 1-meter-base rangefinder was replaced by rangefinders with a base of 1.5 and in some cases 1.75 meters. The fact that the rangefinder was mounted on the gun was a very unhappy solution and was one of the main reasons for the gun's lack of popularity with the troops; direct fire was seriously hampered, and even more so the rangefinding operations, by the

163-164 firing shock, smoke, and the muzzle flash. All of these defects were recognized and were to be remedied in new designs.

For the above reasons, tests were carried with a permanently emplaced battery of these new 50-mm guns in the zone of interior. Here, the guns were controlled byxaxxaxxtrxlxx xixixax separate control pillar, which produced considerably improved performances.

In spite of the excellent results achieved with these weapons under combat conditions because of their longer range and the increased effectiveness of each individual missile, production of the new 50-mm guns was halted. It was realized that a newly designed model incorporating the experience so far gained would result in a greatly improved weapon. Nevertheless,, and in spite of repeated reports from the front emphasizing strongly the favorable points and the effectiveness of the weapon, there was no real impetus behind the work of redesigning. This was due on the one hand to shortage of designing and developing personnel, so that no engineers could be made available for the new project, on the other hand, and particularly so, to the fact that Goering and Hitler were influenced by oral reports from Speer's Ministry and refused to acknowledge the necessity for a weapon of this type. The final result was that all further work on the development of a 50-mm AA gun was prohibited on 2 March 1942.

164-165 The responsible technical development branch attempted a number of times to obtain authorization to resume work on the development of a 50-mm or 57-mm gun, but all efforts failed, and in October 1942 Hitler again stated his decision that the development of a 50-mm gun was out of the question.

In March 1943 Branch E (AAA) of the Special Supply and Procurement Service with support from ~~XXX~~ General von Axthelm, Chief AAA Officer, again took up the subject of development of a 55-mm AA gun with a muzzle velocity of 1,000 meter/second, particularly for defense against armor-protected aircraft operating at low altitudes. In June 1943 a recommendation was submitted that a high priority should be awarded to the new project for the firms of Krupp and Rheinmetall each to manufacture 25 of these guns with a caliber of 55-mm as a trial series. In November 1943 Speer's Ministry again ordered all work halted on the further development of a 55-mm AA gun by the firms of Krupp and Rheinmetall, although the project was in full swing. This interference occurred without the knowledge of the military authorities, which were therefore only able to take counteraction when work on the project had actually ceased and valuable time had again been wasted. After severe remonstrances by the military authorities, work on the projected started again ~~xxxMxx~~ and in May 1944 arrangements were made to test in July the first guns which were to be

164-165 completed ahead of the series. It was hoped that an output of 100 of the new guns could be achieved already from January 1945 on. But again work was delayed by interference, and it was only in January 1945 that authorization was given, in the light of continuing experience, to complete the 55-mm AA gun, but by then it was far too late to have a weapon of this type ready for commitment in the field by the end of the war.

Besides the weapons of German manufacture discussed above all captured automatic weapons were put to use, primarily for home defense. The principal captured weapons were :

the 20-mm Oerlikon gun, internationally knonw,
the 25-mm Hotchkiss hun,
the 40-mm Bofors gun, also in international use.

The 20-mm Oerlikon weapon, which was redesignated for German use as the 20-mm AA gun Model 28, was a weapon developed by the firm of Muehrle in works near Zuerich-Oerlikon, Switzerland and was captured in practically all theaters of operations. It fired ammunition with approximately the same performances as that of the German 20-mm AA guns, but had a shell case differing from the German type. After the stocks of captured ammunition were exhausted, the German shell was used in combination with the Oerlikon shellcase. Its muzzle velocity was 830 meter/second. It was a recoilloader with a reciprocating breechlock (Massenverriegelung) . This use of the reciprocating principle in weapons was a subject of contention, 165-166 since it presupposed extremely precise manufacturing processes to insure a uniform firing cadence. However, the captured weapons proved very satisfactory in combat action. The German Navy also received this type of gun from current production of the firm of Oerlikon; these were used on special boat pivot-swivel mountings and were designated 20-mm AA gun Model 29. The theoretical rate of fire was 250 rounds per minute, but in practice and under field conditions the gun fired 120 rounds perminute. The ammunition was fed to the gun in magazines of fifteen rounds. For use on land the gun had a tripod mount with detachable wheels. Its total movement in elevation was from -15° to +85°. Its elevating speed was 5°, its traversing speed 2.5°, each per revolution of the handwheel. Since the latter speed of movement was inadequate, lateral movement was often by shifting of the tripod supports (Photo 95). The gun was equipped with the German linear sight Model 28. Stripped, and excluding its shield, the gun in firing position weighed roughly 590 pounds (263 kilograms); its riding weight was roughly 737 pounds (335 kilograms.

25-mm Hotchkiss guns were captured in France and were only taken into German service in 1943. This weapon had a muzzle velocity of 900 meter/second , a total movement in elevation of from -3° to +90°, and fired an explosive shell

166-167 weighing approximately ~~550 pounds (250 kilograms)~~ 0.55 pound (250 grams). Its rate of fire was 180 rounds per minute and its effective range probably about 2,200 yards. A self-destroying fuze disintegrated the shell at a distance of 3,300 yards. Its maximum speed of elevation was 5°, and its traversing speed was 15°, each per revolution of the handwheel.

The 40-mm Bofors gun with a barrel length of L/60 was manufactured in a number of couuntries under licence and accordingly was used by these various countries. The construction had been simplified in the various countries and adapted to their own stocks of ma hinery. Thus numerous individual parts of the models coming from various countries were not interchangablewhich caused serious resupply difficulties when the gun was used by German forces. In point of external ballistics, the gun showed better performances than the German 37-mm AA gun. On the other hand its rate of fire was far slower. The theoretical rate of fire was 160 rounds per minute but the maximum achieved under field conditions was 120 rounds per minute. It fired a shell weighing approximately 2.1 pounds (.995 grams) with a muzzle velocity of 850 meter/second. The built-in self-disintegrator functioned after 10.5 seconds, when the projectile had travelled approximately 4,700 yards. The ammunition was fed to the gun in magazines of each four rounds. (photo 96).

167-168 In addition to the weapons so far enumerated a large variety of weapons usually used for mounting in aircraft were also used as antiaircraft weapons towards the end of the war. As a rule these were placed in very simple mounts specially constructed for the purpose and generally used in free firing. They thus had no traversing or elevating mechanisms. Others, such as the 30-mm aircraft cannon Model M.K.103, a blow-back operated gun with ammunition belt, were placed in available light type AA gun mounts, for example

7.9-mm machine gun	Model MG 81	in double-barrel mounts	
15-mm " "	" MG 151/15	in triple-"	"
20-mm " "	" MG 151/20	in " "	"
30-mm automatic cannon	" MK 103	in 20-mmAA mount Model 38.	

As a rule these weapons were used at air bases and towards the end of 1944 frequently to defend targets in the German interior. There, they replaced the 37-mm guns which were urgently needed at the front. They were also mounted on railcars to protect rail transports against air attack. The important problem now was to find means of defense against the increasingly frequent low-altitude air attacks. This requirement was formulated for the first time in September 1944 and it is remarkable how speedily industry and the Technical Office found extemporary solutions for the problem of using all these various types of weapons.

167-168 Finally, a review is offered below of Germany's actual strength of light antiaircraft weapons. Around August 1944 that strength reached its peak. From then on strengths declined owing to losses due to enemy action, reduced factory output due to factory dispalcements and factory destructions. For these reasons the figures for August 1944 and February 1945 are offered for comparison .

Type of Weapon Guns		Number actually in Service	
		August 1944	February 1945
20-mm AA Model 30/38,	mobile	15,900	8,322
	permanently emplaced	1,645	2,178
	Mountain	43	180
20-mm 4-barrel	Mobile	2,120	2,370
	Permanently emplaced	1,485	1,370
	On SP mounts	---	110
37-mm Model 18/36	Mobile	2,900	2,295
	Permanently emplaced	1,300	375
37-mm Model 43	Mobile	283	867
	Permanently emplaced	221	165
37-mm 2-barrel Model 43	Mobile	40	215
	Permanently emplaced	12	176
50-mm Model 41		44	24

Another interestimg comparison is that between the numbers specified for delivers in production contracts and the numbers actually received from industrial output:

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Gun Model AA	Specified for Delivery in 1944-1945	Numbers actually received from output in 1944					
		Jul	Aug	Sep	Oct	Nov	Dec
20-mm Model 38	700	170	170	170	100	100	100
20-mm 4-barrel	1000-3000	200	200	200	275	345	410
37-mm Model 18/36	-	162	162	162	108	90	88
37-mm Model 43	1000	180	246	336	360	450	540
37-mm 2-barrel Model 43	500	18	18	24	84	114	144

This disparity between projected and actual monthly output was not due to any failure on the part of industry but exclusively to inappropriate direction by Speer's Ministry, which operated in a dreamworld of fantastic figures and therefore stated numerical requirements lacking any realistic basis. Another retarding cause was that, as in the case of the 50-mm or 55-mm AA gun, so many conflicting orders were given, which interrupted and hampered work. This was not only the case during the development stages but also during the manufacturing processes, where the Ministry was constantly robbing Peter to pay Paul, so that industry was at no time in the position to meet the stated requirements.

AMMUNITION FOR AUTOMATIC ANTIAIRCRAFT WEAPONS

The fact was recognized already prior to the start of the war in 1939 that little could be done with the normal infantry ammunition against the more sturdily constructed

169-170 aircraft coming into use. The only possibility to bring down a plane was by injuring or killing the pilot or damaging a vital part of the plane. The 5-6 gram (0.176-0.212 ounce) explosive charge planned for the 20-mm high-explosive shell was inadequate to insure destruction of a plane hit, for which reason a certain percentage of the ammunition was to be without the tracer charge and given a larger explosive charge instead, the weight to be 8-10 grams (0.2824-0.353 ounce). This undoubtedly would have considerably increased the effectiveness of the missile, but unfortunately the plan encountered stubborn resistance from the troops. Although not frankly admitted, the main reason was that the troops needed the tracer ammunition to judge their aiming. All troop command agencies allowed themselves to be influenced to assess firing accuracy by the trail of the tracer ammunition, and therefore resisted the discontinuation of tracer ammunition for the purpose of achieving more effective blast effect, so that it was not possible to increase ammunition effectiveness in this way.

However, air pilots themselves repeatedly emphasized the inadequate blast effect of the ammunition of their 20-mm aircraft mounted guns, for which reason every effort was made to develop a 20-mm mine-grenade type of ammunition. The new missile was to be thin-walled with as large an explosive charge as possible. Such changes in the ammunition for

170-171 an automatic weapon is always a highly complicated matter, since the functioning of the weapon permits changes only within very narrow limits. The length must remain unchanged, and the weight can be changed only very slightly, since otherwise the balance between weight and recoil thrust would be distrubed. The flying branch of the Air Force introduced a 20-mm mine-type grenade for aircraft mounted guns, but this projectile tumbled after a flight of only 220 yards because its rotation was inadequate and its weight too small. These drawback could be accepted for aircraft mounted weapons since in those days pilots rarely opened fire on an enemy plane at a longer range. For antiaircraft artillery fire, however, this solution was inacceptable.

For the above reasons a thin-walled shell was produced by cold-drawing processes in which a balanced admixture of explosive and iron powders was used to obtain the proper weight of the explosive shell. The shells thus produced had an explosive charge of 17 grams (0.601 ounce) and tests showed that they had a blast effect 30 percent greater than the normal 20-mm shell. However, no workshops were available which could have handled the manufacturing processes, so that this type of ammunition did not go into mass production.

The fuze of the 20-mm shell proved to be too sensitive, causing the shell to detonate before it penetrated into the

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171-172 aircraft. Initially, production specifications had stipulated this super-sensitivity of the fuzes, but it was soon recognized that the effect would be greater if the shell could explode inside the target. Three firms, namely, Troisdorf, Rheinmetall, and D.M.W. conducted tests to find a solution, and the firm of D.M.W. introduced a change in the percussion cap, with which the shell exploded only 20-27 inches (50-70 centimeter) after penetrating the aluminium XXXXXXXXXX hull of the aircraft. The introduction of this fuze with the modified percussion cap brought about an improvement in the effectiveness of the 20-mm shell. The weigh of the shell with its explosive and tracer charges was 115 grams (4.06 ounces).

From about 1943 on a flammable additive furnished an incendiarey shell for the antiaircraft artillery. Since this additive would otherwise have reduced the blast effect, a certain percentage of the ammunition from then on was produced without the tracer element.

For antitank fire in ground combat, the guns fired an armor-piercing shell, in some cases with a phosphorus filling Wolfram would have been the best solution for these armor-piercing shells, but since only very limited quantities of this valuable alloy were available and were more urgently needed for other purposes, the antiaircraft artillery with

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172-173 its heavy expenditure of ammunition had to do without it and used shell heads of hardened steel instead.

Troops in the field frequently insisted that armor-piercing shells should also be furnished for use against armor protected aircraft, in the belief that normal shells had been seen bouncing off the armor plating of such aircraft. This was due to an optical delusion in many cases, since it happened often that when a shell struck its target the tracer element fell off. Seen from the ground, this naturally looked like the whole missile bouncing off the aircraft hull, an impression which was strengthened when the obvious hit produced no visible results. The failure to produce results, however, was due to the previously mentioned inadequate effectiveness of the 20-mm shell. In order to use armor-piercing ammunition against aircraft, speedy action had to be taken to devise means to insure disintegration of the shell. The solution was found very soon and ammunition of this type was supplied to combat troops already in 1941. In order not to forfeit the greater effectiveness of the normal explosive shell, however, hig-explosive and armor-piercing shells were fired laternately, being loade this way in the magazines, and there was no way to determine which ammunition was responsible when a plane was brought down.

172-173 Troops in the field also insisted that the hoolow-charge principle should be exploited for ammunition for the 20-mm weapon in action against tanks. This would only have been possible by using a cup-nose grenade (Bechergranate) with a diameter of 8 centimeters, which would have had to be inserted in the muzzle of the gun and in combat this would hardly have been possible. Other drawbacks were that gunbarrel attrition would have been far higher, the whole gun would have suffered, and the functioning of the weapon would have been jeopardized. These suggestions therefore had to be rejected.

The following types of ammunition were thus in use for 20-mm antiaircraft guns:

20-mm explosive grenade cartridge

20-mm incendiary-explosive grenade cartridge with tracer and self-disintegrator

20-mm incendiary-explosive grenade cartridge without tracer but with self-disintegrator

20-mm Armor-piercing cartridge with tracer, without self-disintegrator

20-mm armor-piercing cartridge with tracer and self-disintegrator.

In the case of ammunition for 37-mm caliber guns, circumstances were similar to those in the case of 20-mm ammunition. The blast effect of the individual 37-mm shell with its ex losive charge of 28 grams (0.8483 ounce) could on the whole be considered adequate at the time, but here also the fuze had to be changed so that the shell would explode inside the target airplane. In May 1943 the troops received their

173-174 first issued of mine-type grenades with a 90 gram (2.727 ounce explosive charge for field trials. The new ammunition proved satisfactory, and from the end of 1943 on thr principle types in use for antiaircraft fire were

the combined incendiary-explosive shell with reduced tracer and the mine-type shell.

For antitank action the gun naturally used an armor-piercing shell .

When the Model 43 37-mm AA gun was introduced with its considerably increased rate of fire, the recoil action naturally placed greater strains and stresses on the ammunition. Numerous cases occurred in which destruction of the duplex cover caused shellburst in the barrel, which rendered the weapon unserviceable and unfortunately also caused casualties in dead and wounded. Here again progress was bound by existing circumstances, and it was required that the new gun must be able to fire the types of ammunition produced in masses. This meant that the improved performance capabilities of the new weapon had to be sacrificed, and in this weapon in particular improved performances would have been highly desirable, since its external ballistic features could no longer be considered up to date. All this was the outcome of the neglect with which this caliber had been treated in the pre-war years up to 1939. Under conditions of war it is always particularly difficult

174-175 to remedy mistakes of the past. Usually half-measures have to be adopted under the pressure of current circumstances as in this case, in which the improved performance capabilities of a weapon had to be sacrificed in order not to jeopardize the supply of adequate quantities of ammunition to the troops in the field.

Another item which had been neglected during peace and now had to be dealt with was introduction of iron shell rotation bands. Copper was becoming increasingly scarce, and adaptation to iron rotation bands was therefore inescapable. Simultaneously with introduction of the new 37-mm Model 43 AA gun in 1943, shells with iron bands instead of two copper bands were also introduced. This resulted not only in a more economic use of copper but also in simplified manufacturing processes. Instead of the two copper bands formerly needed, only one iron band was required, so that the second groove no longer had to be cut on the shell. The new ammunition was also suitable for use in the old Models 18 and 36 37-mm barrels, whereas the new Model 43 37-mm barrels could not fire the old type of ammunition with two shell rotation bands, which later was also no longer used in new barrels supplied for the older model guns. When fired from old barrels of the older gun models, the new single-rotation-band shells first had a short free-flight space before receiving their rotation in the gun barrel rifling

175-176 grooves . No evident disadvantage resulted in weapons of this caliber, and barrel attrition also remained within the normal limits. Both types of barrels and also both types of ammunition were still in service at the fronts when the war ended in 1945. In spite of all precautions taken, it happened frpeatedly that units equipped with new barrels received the wrong type of ammunition.

For the 50-mm Model 41 AA gun an explosive grenade cartridge with tracer and also a combined incendiary-explosive shell with tracer were developed on the basis of experience with the 20-mm and 37-mm ammunition. The fuze used here had two self-disintegrators for differing distances, which had to be set according to the barrel elevation. The intention here was to prevent shells exploding after returning to the ground and at the same time to exploit firing range capabilities to a maximum. The self-disintegrators could be set at 5-8 seconds=3,300 to 4,510 yards, or at 14-18 seconds=6,490 to 7,370 yards. The projectile weighed 2.2 kilograms (4.84 pounds) and had an explosiv charge of 90 grams (2.727 ounces). The gun also fired an armor-piercing shell for antitank action.

For the 55-mm AA gun still under development, barrel tests had reached the stage at which the type of shell it was to use could be decided. This shell was to weigh 1.8 kilograms (3.968 pounds), with an explosive charge of 450 grams (roughly 1

176-177 pound) and was to be fired with a muzzle velocity of roughly 1,000 meter/second. These ammunition particulars in themselves reveal how great the effects of the shells fired by this gun would have been, and how significant the introduction of guns with this caliber would have been. This makes it all the more hard to understand that technical experts such as those available in the Ministry opposed this development project.

Also of interest is the average monthly expenditure of AA ammunition in 1944, as follows

20-mm caliber shells	monthly	8,567,700
37-mm caliber shells	monthly	931,900.

The largest expenditure of light AA ammunition for the whole year of 1944 was in November of that year:

20-mm caliber shells	11,628,440
37-mm caliber shells	1,038,470.

In the light of these figures one can also understand the decision taken in August 1944 that, in view of the anticipated increase in the number of guns and the increasing frequency of enemy air penetrations, the monthly output in light AA ammunition was to be increased from March 1945 on to

21,000,000 20-mm shells
4,000,000 37-mm shells.

These figures are mentioned here specifically to show clearly what demands are made on the ammunition manufacturing industries in times of war.

RANGEFINDING AND SIGHTING EQUIPMENT FOR AUTOMATIC AA WEAPONS

This was a very disappointing field, since all attempts to exploit technicological progress here met with a complete lack of understanding on the part of the troops, who in practice even preferred to take a step backwards instead of availing themselves of the technical possibilities offered. The following account is offered to illustrate what happened.

Increasing aircraft speeds and operating altitudes meant that greater demands had to be made on sighting devices.

In the case of ~~AUTOMATIC WEAPONS~~ AA machine guns, which had only a relatively short range of effective fire, the ring sight was retained. This principle had to be retained because other systems were impracticable because of their weight for these weapons.

Circumstances were different for automatic weapons in the 20-mm and 37-mm caliber classes, and particularly so for 50-mm or 55-mm weapons. The two models in use, Model 35 for ranges up to 2,970 yards and target speeds of 120meter/second, and Model 35 for ranges up to 3,880 yards and target speeds of 120 meter/second, had both been improved for target speeds of up to 170 meter/second. The weak point in these instruments was that the factors for target speed, range and direction of flight had to be hand set, which required time

177-178 and manpower. The demand had therefore always existed for sighting devices functioning without the necessity for presetting of the data factors. This had given rise to development of the electrically operated sighting instrument, which functioned automatically, the movements of the elevating and traversing mechanisms being automatically translated into lead factors. Model 41 AA sighting device had a range between 550 and 6,100 yards. With a 60° angle of view and a maximum lead angle of plus-minus 30°, this instrument constituted a considerable step forward. The only data factors requiring hand setting was that for range, which could only be set after the gunner had the target in the sighting cross-wires (Fadenkreuz) ; otherwise the rapid movements of the gun barrel until focussed on the target would have registered faulty lead data in the sight. Besides a gun-layer, this device therefore also required one man to set the ranga factor and switch on the mechanism as soon as the gun pointer had focussed on the target. This equipment thus embodied definitely important advantages and it was very regrettable that the troops rejected its use from the outset, so that it was not generally introduced although already in mass production.

The negative attitude of the troops towards the new sighting device is explained by the fact that the staff

178-179 of instructors at the AAA school, which was responsible for the direction of all training, had not at once recognized the basic features of the new instrument. Because of its sensitive reactions, the new device presupposed thorough training of the pointing gunner. Using the old sighting devices, the pointing gunner also had to keep the target constantly in his cross-wires, but it was not so direly important if he failed to do so because in such case he immediately had the correct ~~data~~ lead data again in his sights for readjustment of aim after his first round. Things were different in the new instrument. Here the slightest delay in following data with the barrel and any consequent readjustment affected the sighting setting, and faulty lead factors resulted. The pointing gunner thus had to follow the target even while firing and even when actual sight of the target was lost temporarily because of an intervening cloud. Each gunner should have been made aware of this necessity and trained accordingly. The training school had not understood this necessity properly and in any case had failed to give thorough training on this point.

It is always particularly difficult and in many cases impossible to retrain experienced guncrews to use new instruments, and in this case it again became evident how difficult it is to introduce something to the troops

179-180 which differs from what they have been taught in training or which was not included at all in their training program.

It seems that even the AAA School had not recognized the essential characteristics of the new sighting equipment. Neither had it recognized that the essential necessity was to retrain pointing gunner--and consequently had given no instructions for such retraining, nor had it drawn the proper conclusions from its tests with the equipment.

What the School did notice was that with the electric clockwork sighting equipment fire was placed even wider of the mark than with the old equipment, and that even when the older ring sight was used. From this fact it drew the conclusion that the new equipment was useless instead of investigating the causes of this faulty aiming. The School failed to realize that this was not due to any fault in the equipment but solely to the fact that faulty range data was being fed into the instrument. As was usual with 20-mm caliber weapons, use was made in the tests of the 1-meter-base rangefinder which was known to provide only very inaccurate range data with the possibility of errors as great as plus-minus 275 yards, and for the sighting equipment using automatically computed data factors, such data was not accurate enough.

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179-180 In the case of a simple sighting system, faulty range data might be compensated by other errors, for which numerous possibilities exist. In the case of a computing mechanism such as an automatically functioning gunsight device, however, any such faulty data factor fed to the mechanism is at once multiplied, and necessarily results in faulty fire.

Units using the new equipment should have been supplied improved rangefinders with a wider base at the same time. This necessity is what the School should have realized from the results of its tests instead of simply stamping the new equipment as unsuitable for use and rejecting its introduction. This fact was confirmed immediately when the School repeated its tests with a 4-meter based rangefinder. By that time, however, aversion to the new sighting equipment had taken such firm root among the troops that it had to be withdrawn from use and, in spite of protests by the responsible military-technical agency all of the instruments were scrapped.

The proper course of action would have been to use the new sighting device with a better rangefinder and to insure appropriate thorough training of the pointing gunners. As is the case with all automatic sighting devices, the new equipment had the inherent weakness that it could not immediately follow abrupt and unexpected target changes. it needed

180-181 a certain space of time for the first adjustments and again a certain space of time for any further adjustment which migh become necessary. There might have been some justification for describing the new equipment as over-developed, but the aversion shown by the School and by the troops was in no way justifiable or logical. Pointing gunners who had grasped the principles of the new equipment and used it willingly achieved excellent results in the number of planes downed by them. To this end, however, they had to be furnished better rangefinders with a 1.5 or 1.75-meter baseproviding more reliable range data. Within my own personal field of authority I adopted these measures and achieved excellent results, particularly with 20-mm four-barrel and with 37-mm weapons.

The School raised the objection that after the target was focussed a certain amount of time passed before fire coul be delivered. Its aversion to the new sighting equipment was so deeply rooted that it refused to use it in training becaus its handling allegedly was too complicated. The personnel "now available at the end of the war in 1943-1944," it stated was incapable of understanding and using it to good purpose. In this way the School implanted a general aversion to the innovation and a general preference was shown for the most simple instruments available.

The School itself favored a very simple ring sight and

181-182 was actively participating in such a development. It was therefore not free of prejudice in its appraisal of other aiming devices, a circumstance which was destined to have xxx such fateful consequences. The ring sights in use were known already to be inadequate, and in a spirit of self-deception the idea was to add certain improvements by constructing a pivot ring sight, the external appearance of which was to create the impression of something entirely new and promising having been invented. However, devices of this kind are all adequate only for aiming by the tracer trail, and this fact limits the effectiveness of all weapons equipped with these devices to a range of 660 yards, whether they have a caliber of 20-mm, 37-mm, or 50-mm. Furthermore, it was not possible with the naked eye to determine the deviation of the tracer trail from the target. The measures taken, and the introduction of the pivot ring sight thus served to prove once again, that those responsible still adhered to the principle of aiming by the tracer trail and believed that the data gathered by observing the tracer trail of trial shots could be translated into firing data speedily enough for effective fire at the same target, even where aircraft travelling at modern speeds were concerned. Added to the above came the fact that, shortly after the start of the war in 1939 the second rangefinder ~~xxxxxxxxxxxxxxx~~

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182-183 instrument previously assigned with automatic weapons had been taken away, and that later it was not even each gun but only each platoon of three guns which was assigned one rangefinder operator and instrument. This completely robbed the gunner of any possibility at all to assess the position of the tracer trail in relation to the position of the target --which is the very principle of firing by tracer trail, at distances beyond 660 yards. It is an actual fact that this system of aiming and firing was required, with even more emphasis than ever before, in utter disregard of the fact that the gunner had been deprived of the essential means required in this system, namely, the rangefinder. One could argue thatthe rangefinder operator could have taken over this function of assessing the position of the tracer in relation to that of the target. This would be a fallacy, however, since it is an acknowledged fact that the rangefinder operator can either determine the range or observe the placing of the fire. If he is burdened with both functions, performances in both functions will suffer since neitherof the two is a simple matter.

What has been said above is still of significance under present conditions, since many still advocate the principle of aiming and firning by tracer trail, and it is impossible to emphasize too strongly the danger of succumbing to this

182-183 fallacy.

For light antiaircraft weapons there were three different rangefinder models available, all based on the principle of the stereoscopic range finder. The models were as follows:

Model 1-m R or 36	weighing	11 and 16.5 lbs, respectively
" 1.25 m R	"	17.16 lbs
" 1.75 m R	"	24.2 lbs.

Since the operator had to carry his rangefinder instrument by a shoulder strap, weight was an important consideration. For this reason, the 1.75 meter base rangefinder could not be used with 20-mm and 37-mm weapons. As explained previously in this study the 50-mm gun had its rangefinder on a mount next to the gun (Photos 92, 93, 94), for which reason the 1.75 meter base instrument was already in use for these calibers.

The operating ranges of the various instruments were as follows:

Model 1 m R	275-8,800 yards	with a magnifying power of 8
Model 1 m 36	550-11,000 "	" " " of 6
Model 1.25 m R	550-8,800 "	" " " " 12
Model 1.75 m R	550-8,800 "	" " " " 15

Construction of these instruments had always constituted a bottleneck, since the firms producing them were fully occupied in manufacturing fire control director equipment and searchlights. Thus, the equipment quota of 1 meter base rangefinders for 20-mm and 37-mm AA batteries was drastically curtailed already at the start of the war, and in mid-1943

183-184 serious consideration was even given to a complete halt in the production of 1 and 1.25 meter base rangefinders in favor of the manufacture of Model 40 fire control director equipment. In May 1944 the manufacture of 1.25 meter base range finders was actually halted and all newly activated units, including batteries with 37-mm Model 43 AA guns were to be equipped exclusively with the 1 meter base model, and any rangefinder instruments which were lost or became unservicable were also to be replaced exclusively by 1 meter base models.

In closing this account of a long series of disappointing events, the responsible authorities are warned not to treat the matter of aiming equipment for light AA weapons lightly and superficially in the future, since such weapons are completely valueless without proper firing instruments. To use even the best weapon without a proper sighting device is an act of sheer irresponsibility, and it is hoped that this lesson will at least have been learned from past experience.

HEAVY ANTIAIRCRAFT GUNS

As an initial step the new 105-mm AA gun Model 39 (Photo 97), development of which had meanwhile been completed, was introduced early in 1940 to replace the 105-mm model taken over from the Navy. The new weapon could be used as

184-185 a mobile gun with Special Type Trailer 203, but was mounted preferably on railcars. It had a maximum movement in elevation of -3° to $+87^{\circ}$ and a rate of fire under field conditions of 8-10 rounds per minute. Its pivot mount had electrically driven elevating and traversing mechanisms as well as an electrically driven automatic loader. It fired a 33.2-pound (15.1 kilogram) missile with a muzzle velocity of 880 meter/second. The weight of the shell with casing was 22.52 lbs (15.1 kilograms) so that handloading was not possible. Stripped weight of the gun in firing position was 22,528 lbs (10,240 kilograms) and riding weight, including Special Type Trailer 203,was 29,200 lbs (14,600 kilograms). From the technical aspect the manufacturing requirements for this gun were unsatisfactory. Furthermore, the various electrically operated devices introduced with this model for the first time showed certain weaknesses and on the whole the initial weakness which became apparent in the weapon were never fully remedied.

When its ballistic performances were superceded in 1942 by those of the new 88-mm Model 41 weapon, the intention was to cease its production in order to produce an increased number of the new model 88-mm guns. That this plan did not materialize was due to the obsession of Speer's Ministry with numbers, and the fear that for a few months its reports

183 would have shown a smaller output of heavy caliber guns.

In December 1942 the Military Technical Office suggested simply placing an 88-mm Model 41 barrely on the pivot mount, which would have produced a weapon with considerably improved performances. However, this solution, as well as all other solutions tried, was thwarted by the ammunition problem. The quality of ammunition could not be improved to meet the requirements of the new 88-mm barrel because of a shortage of Guanidin powder, a powder with a low combustion temperature.

In August 1943 it was decided to manufacture only 100 205-mm guns monthly, instead of 150, but unfortunately the decision to let this model go out of production was not maintained. Instead, the demand was made in August 1944 to again step up its production to 200 mobthly up to the end of 1945.

In August 1944 there were actually in service 2,018 of these 105-mm AA guns, 1,025 of the mobile, 877 permanently emplaced, and 166 mounted on railcars. The total number in service in February 1945 was 1,863, of which number 884 were mobile, 869 permanently emplaced, and 110 mounted on railcars.

Also of interest here is the number of such guns it was hoped could be produced in April 1945, namely a total of only fifteen.

Guns from the first series of 128-mm guns manufactured

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185-186 reached the troops from the end of 1941 on, followed in 1942 by the first 128-mm double-barrel battery delivered by the firm of Hanomag.

The 128-mm gun was on a swivel mount with electrically driven elevating and traversing gear and an electrically driven automatic loader. The new weapons could fire 10-12 rounds per minute. It could be towed on Special Type Trailer 220. It fired a projectile weighing 57.2 lbs (26 kilograms) with a muzzle velocity of 880 meter/second. The shell with casing weighed 104.94 lbs (47.7 kilograms). Stripped weight of the (single-barrel) gun in firing position was 37,400 lbs., riding weight on its special trailer was 37,200 lbs (17,000 kilograms). However this weapon was used only in permanent emplacements or permanently mounted on railcars. It had a total movement in elevation of from -3° to $+87^{\circ}$ (Photos 98, 99, and 100). Its maximum firing altitude was 46,200 feet, so that it could be used effectively against targets at an altitude of 33,000 feet. On double-barrel mounts these guns were placed in AA towers.

Experience gained with the 105-mm gun proved helpful in developing the new 128-mm weapon, which proved excellent in permanent positions. Due to its heavier caliber it naturally had a considerably greater blast effect per individual shell fired.

On 4 June 1942 the decision was finally taken to

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186-187 to use all 128-mm AA guns coming from current output for emplacement in permanent positions, which can probably be considered a justifiable decision in view of its caliber and weight. Production was to be stepped up, for which purpose new premises were to be installed in the Hanomag factory for a monthly production of 30 barrels; approval was given for this on 7 September 1942. This was probably the most effective antiaircraft gun used in the war from 1939-1945.

The blueprint series were completed by March 1943, so that the gun could go into mass production. Plans provided for an output of 25 double-barrel and 100 single-barrel guns monthly, while the monthly production of 105-mm guns was to be reduced by 100 ~~monthly~~. Unfortunately the planned output was never achieved, the number of 128-mm guns delivered by industry from July-December 1944 being as follows:

	Double-Barrel	Single-Barrel
July	1	38
August	2	38
September	4	38
October	9	54
November	10	60
December	12	71

From December 1944 on the monthly output again decreased and in April 1945 only between fifteen and twenty of the new guns were expected from current output.

The actual strength in 128-mm AA weapons in August 1944 totalled

187-188	for use as mobile units	6 guns
	permanently emplaced	242 "
	mounted on railcars	207 "
	double-barrel mounts	27

The numbers in service in February 1945 were as follows

for use as mobile units	4 guns
permanently emplaced	362 "
mounted on railcars	195 "
double-barrel guns	34 "

Work also commenced in December 1943 on a project to improve still further the performances of the 128-mm AA gun, and the first designs were submitted in May 1944. These provided for a longer barrel to fire the type of shell used by the Navy with a conical lug (Zapfen) and weighing 61.6 pounds (28 kilograms). So far as I am informed, the new model 128-mm gun did not go into field service by the end of the war.

No further manufacturing contracts were awarded for the 150-mm guns completed already prior to the start of the war in 1939 by the firms of Krupp and Rheinmetall, the reasons being the results of tests by Weapons and Equipment Proving Branch 10. Both models featured a pivot mount with electro-hydraulic elevating and traversing mechanisms. A fully automatic loading device with roller feed and hoist was to handle the shells, which had a weight of 88 pounds (40 kilograms). The gun was to fire nine rounds per minute

188-189 with a muzzle velocity of 890 meter/second. The stripped weight of the gun in firing position was 48,800 pounds (22,200 kilograms). The maximum firing altitude was slightly higher than that of the 128-mm gun, namely, 16,720 yards. (photo 101).

Work continued until 1943 on development of an improved 150-mm AA gun, and in May 1943 a start was to be made at manufacturing a test model, to be completed within a year, which ~~xxxxxx~~ was to fire a missile to an altitude of 19,800 yards in approximately 25 seconds. Muzzle velocity was to be 1,200 meter/second and it was assumed that the service life of the barrel would last only 86 rounds. In September 1943 Speer's Ministry rejected continued work on this project, and Hitler and Goering supported this decision. The Military Technical Office obtained authorization at least to continue barrel experiments and barrel firing tests with the object of using the barrel to launch rocket-propelled shells instead of conventional shells with a muzzle velocity of 1,200 meter/second. In November 1943, however, even these possibilities were lost when all further experiments and tests with 150-mm caliber weapons were prohibited and orders given to place special emphasis on improving the performances of 128-mm guns instead.

Renewed requests for authorization to continue tests with the 150-mm weapon were finally rejected in June 1944.

189 The ludicrous part of this rejection was that it was accompanied by instructions to complete the trial models of the gun. How the General Staff and the Ministry expected this to be done remained their own secret.

Due to the circumstances just described, individual parts of the 150-mm AA gun still under development were at the developing firms when the war ended, but no servicable gun of this type was ever completed. In this way the constant back and forth of instructions and counter-instructions not only hampered development work but at the same time wasted valuable time, which everything possible should have been done to avoid.

All of the weapons dealt with above were far too heavy for mobile operations. The increasing altitudes at which antiaircraft fire compelled enemy air forces to operate made it an inescapable necessity for the antiaircraft artillery development branches to devise a mobile AA gun capable of e fe effective action against targets at altitudes above 19,800 feet and if possible up to 33,000 feet. With wise foresight Colonel Mertitsch, at that time Chief of Weapons and Equipment Proving Branch 10, immediately after the start of the war had assigned to the firms of Krupp and Rheinmetall research and development projects for weapons with such performances. The outcome was that th firm of Rheinmetall as

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189-190 early as in 1941 was able to submit for trial a gun of this type, namely the 88-mm AA gun, Model 41.

This gun stood on a turnstile mount (Drehkreuzlafette) with a low firing height of 1,250 meters, compared with the 1,600 meters (1,760 yards) of the 88-mm AA gun Model 36. It had a semi-automatic breech-block, a hydro-pneumatic roller attachment, and achieved a rate of fire of 20-25 rounds per minute. It had a shield and was tractor-towed on Special Type trailer 202. Its muzzle velocity was 1,020 meter/second and its shell weighed 20.68 pounds (9.4 kilograms). Its maximum firing altitude of 16,170 yards made effective action against targets at altitudes up to 33,000 feet possible.

In point of exterior ballistics this new weapon was thus considerably superior in its performances to the 105-mm AA gun and almost equal to the 128-mm and 150-mm guns (Photos 102, 103, and 104). It could be said without exaggeration that this weapon was a development considerably ahead of its time, and that it would retain its importance in the foreseeable future. Its stripped weight in firing position was 17,600 pounds, its riding weight on the trailer 12,320 pounds.

Unfortunately, the responsible technologists in Speer's Ministry at the time failed to realize the significance of the new weapon. Instead, they found fault with the fact that it required approximately 220 pounds more material to

190-191 manufacture than the existing 88-mm model, and that the construction plans specified the use of aluminum for certain parts to cut down weight. This resulted in an order from Hitler dated 19 March 1942 that the production of this gun was to be restricted to the 44 already on order and that no further contracts were to be placed, and that the guns delivered were not to be assigned in the field but were to be used to protect targets within the German interior.

The first guns of the new model came from the factories in August 1942, at the time when Rommel's complaints arrived from Africa that the older Model 36 type of 88-mm AA guns were no longer adequate for action against the new heavy types of tanks employed by the enemy. Hitler thereupon spontaneously demanded the transfer of the 44 88-mm Model 41 AA guns from the C-series to Africa, and rejected all objections to this decision. As is to be expected in the case of any newly introduced weapon, setbacks and difficulties were to be expected with the new gun. Furthermore, the individual parts of the new weapon were not readily exchangable, but always had to be specially fitted, for which purpose the guns were returned to the factory workshops. Had the guns remained within Germany, as originally planned, and if they had been assigned to protect targets as close as possible to the manufacturing firm, these defects could have been remedied speedily and

191-192 the firm would have been able to make the necessary alterations to the manufacturing blueprints, and thegun certainly would soon have become popular with the troops.

Unfortunately, it is not possible to exonerate the AA School from a share in the blame for the above faulty decision, because it was that School which from the outset during tests with the gun had reiterated time and again that this weapon with its low firing height was particularly suitable for antitank action. Since most of the officers on the Staff of the school came from the field in the combat areas, and only a few were from the home defense units, one can understand the prevalence of such views there, but unfortunately these views in this particular case were destined to have fateful consequences. The fact that the gun had been developed primarily as an antiaircraft weapon and not as an antitank gun was simply disregarded.

During transportation to Africa 50 percent of the guns were lost in ships sunk, so that only approximately twenty of the guns arrived in Africa. And, as the Military Technical Office had predicted, these guns were only in the field for a short while at a time, having to be sent back to the workshops whenever any new part had to be fitted.

Shipment of the guns to Africa had also made it necessary to send along a specially equipped mobile workshop.

191-192 Another disadvantage of the gun, for conditions in Africa, was that its barrel was in five sections . This simplified manufacturing processes and also was designed to facilitate the exchangability of parts of the barrel which might become defective. Since use was made initially of brass shell cases, it was not discovered at once that this barrel structure would prove unsatisfactory when steel shell cases were used. Adoption of a four-section barrel failed to remedy the defects which then became evident. In both the five-section and four-section barrel that part of the inner tube which was not rifled was manufactured separately, so that there was a ~~xixxx~~ groove in that part of the barrel where the shell case rested. The empty shell cases jammed in this groove and could not be ejected. When this weakness had been discovered and barrels were to be constructed in three sections, Speer's Ministry once again caused difficulties and was not willing to convert to the manufacture of three-section tubes until March 1944.

Shell cases of tempered steel (verguetarter Stahl)would have served to improve the shellcase ejection action, but this solution was frustrated by the fact that there were not sufficient tempering ovens available for the immense quantities of ammunition needed.

All of these complications and difficulties naturally

192-193 had a particularly hampering effect under conditions in Africa and the troops therefore had to rely on the old model 88-mm antiaircraft gun for defense against enemy tanks, which did not prove too difficult a matter. This fact showed once again that the troop commands were not always objective in their reports and thereby did much harm. A similar occurrence has been reported previously in this study, that of the adverse troop reports on the 37-mm AA gun during the campaign in Spain in 1936-1937, and in 1942-1943 the same thing happened with the 88-mm AA gun Model 41 in Africa.

The outcome of the whole matter was that the order to cease deliveries of 88-mm AA guns of the Model 41 type was suddenly forgotten and it was completely impossible to produce sufficient numbers of these weapons to meet all demands. In October 1943 Hitler demanded a monthly output of 100 guns of this type, but now the results of the order dated in March 1941 to place no further orders for these guns made themselves felt. The outcome was that, after the C-Series delivered to the front in August-Se tember 1943, further deliveries could only be stepped up very slowly, as follows:

April 1944	3	guns
May	24	"
June	30	"
July	37	"
August	47	"
September	62	"

193-194 October 1944 72 guns
November 1944 87 guns and for the first time in
December 1944 100 guns.

The totalstrength in 88-mm AA guns of the Model 41 type available in August 1944 was 159, which mounted by February 1945 to a total of 279. The majority of these guns were now committed in the German interior, but only after a number of them in Africa had been captured by the enemy, who now had knowledge of this new weapon.

In efforts to accelerate production of the new weapon, the production of 88-mm AA guns Model 36 and of 105-mm guns Model 39 had been reduced and the intention was to let these guns go out of production soon. Without informing the appropriate military authorities, Speer's Ministry had even reduced the production of 128-mm guns, and the worst was only averted in this respect by energetic intervention on the part of the Inspector of Antiaircraft Artillery, General von Axthelm. This should serve as sufficient proof of how important it is not to leave such decisions to the industrial authorities alone.

As early as in April 1943 the problem was taken under study of how the performances of the old type 88-mm AA guns could be improved to as close as possible to the performances of the 88-mm AA gun Model 41.

The gun problem as such was speedily solved, due to

194 the many years of preparatory work which had been done in the field of muzzle brakes. In the first place the very old models of the 88-mm gun, the Model 18 types, proved suitable, of which 2,000 were still in existence. The barrel of this gun was lengthened and given the loading area of the Model 41 gun; a muzzle brake was affixed, the fuze setting mechanism XXXIX fixxx and loading apparatus were modified to the requirements of ammunition for the 88-mm gun Model 41, and the equilibrator springs were reinforced. The speed at which this constructional work was performed was not fast enough, however, for Speer's Ministry which pressed almost weekly for information on the current status of development.

When the readapted guns was ready, however, the same Ministry in spite of its attentioan having been drawn to the fact during the readaptation processes, had overlooked the fact that ammunition for the 88-mm gun Model 41 was a special production item, and that the current output was inadequate . This would have been the case even for the normally increasing output of the original new model, and the problem now was, how to procure this ammunition for the improved 88-mm guns of the Model 18 and 36 types. This matter is only mentioned incidentally here, because it will be necessary to return to it in the later discussion of ammunition.

While the above work was in process plans had also been

194 prepared for the use of 88-mm AA Model 41 barrels in 105-mm AA gun mounts and thereby also secure imporved gun performances in that weapon. These plans were also frustrated finally by the ammunition problem.

Concerning the tried and tested 88-mm AA Model 36 gun it remains to be said here that it proved necessary during the war to provide it with a shield for use at the front as an antitank weapon. This subsequent addition to the weapon was by no means simple, and the illustration in Photo 105 serves to show the adverse effects of such subsequent requirements.

In August 1942 the troops and the AAA Inspectorate requested the accelerated production of the 88-mm AA Model 36 gun on a self-propelled mount. Due to the fact that such a development was already in process since 1941, the firm of Krupp was able to submit its first trial model of this type of weapon in April 1943, followed in May by an 88-mm AA Model 41 gun on a self-propelled mount, so that a zero series could go into production for delivery at the end of 1943. As an intermediate solution, the Model 36 88-mm AA gun was to be provided with improvized armor protection on the 18-ton standard tractor. Thirty such batteries were to be organized, but initially the Army failed to make the necessary tractors available for the purpose, although it was the Army itself which had pressed for this solution. The requirement of the Army that the gun should be

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195 detachable from the mount could not be met because the weight of this gun made this impossible without special auxiliary equipment. A construction meeting such requirements is simply not possible as an immediate solution (Photo 106).

From early 1943 on the firms of Krupp and Rheinmetall worked continuously on the development of antiaircraft tanks. Space considerations made it necessary to modify the gun, which was finally designated as the 88-mm AA Model 42 gun. Krupp had instructions to find a solution involving a new xxxxx chassis, but making use of construction elements of the Mark IV tank. Work on this project was halted in December 1943 afte trial models had been constructed, which were delivered to the front line forces early in 1944. (Photo 107). Krupp was assigned a new project, that of developing an 88-mm AA tank using the multi-purpose tank chassis introduced in the Army.

Rheinmetall developed a three-quarter ton closed AA tank with a traversable turret, using the Panther tank chassis. The trial model was to be ready by the end of 1944. The war ended before this weapon went into service in the field. Mention must also be made of the use of railcar-mounted antiaircra-craft guns in the Railway AA Branch (Eisenbahnflak), which was organized as early as in 1941 (Photo 108).

In February 1941 the AAA Inspectorate called for the development of a heavy caliber AA gun for permanent

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196-197 emplacements. Branch 6 of the Air Force General Staff disapproved the development of such a weapon and instead demanded the development of antiaircraft rocket weapons but gave only very vague indications of what it had in viewand probably was still thinking in terms of unguided rocket missiles. Preliminary discussions nevertheless took place with the firms of Krupp and Rheinmetall concerning a very heavy caliber antiaircraft gun, recommendations gradually evolving around a caliber of 240-mm. In 1941 Goering disapproved any further steps in this direction. However, since Goering also opposed the development of antiaircraft rocket weapons, nothing whatever was done in either of these two possible fields of endeavour.

At the beginning of 1942 the Chief Antiaircraft Artillery Officer (General der Flakwaffe), General Axthelm, drew up a development program, which was approved by Goering on 1 September of the same year (Appendix 3). This program under Head B (2) renewed the d mand for the development of superheavy antiaircraft guns in the 200- to 250-mm category. There now seemed to be no more obstacles in the way of the development of such guns and an energetic start at the was was made. But a month later already, when it became known on the basis of the first research results and reports from the firms, that a servicable life for the barrels of only 120 rounds could be assumed, the highest authorities again adopted a declining attitude towards

197 the project.

In December 1942 Branch E (AAA) of the Office of the Chief of Special Supply and Procurement clarified the situation concerning further development of a 240-mm antiaircraft gun, stating that the idea was not to develop a weapon of the conventional type, but that a rocket attachment was intended for the new weapon, that a proximity fuze was specified, and that the plan was to provide the missile to be fired by the new weapon with a homing device. On the basis work was allow- to continue at least for the time being.

Already in mid-October 1942, Minister Speer in a conference at Hitler's Headquarters declared the memorandum of the Air Force on the subject of the development of the new weapon as utopian, a view which Hitler supported. From this fact it is evident how unwilling Speer's Ministry was to support the development project in the direction approved by Goering.

Pursuant to orders from Hitler and from Minister Speer, the staffs of the developing firms were again seriously reduced in January 1943, which compelled the firms to declare that if the difficult personnel situation remained unchanged it could not be presumed that a 240-mm antiaircraft weapon could be completed before 1948, and in the past the stated deadline for completion had been the end of 1945.

This situation was exactly what Minister Speer had

197-198 wanted; ~~xxx~~ it provided him with the opportunity to prevent any further work on development of guns of this type, and on 17 August 1943 Hitler and Goering prohibited any further work on the development of a 240-mm antiaircraft gun.

As early as in September 1942 Minister Speer had in an oral report to Hitler stated his opinion that it was unnecessary to provide gun carriages for antiaircraft guns committed within the zone of interior, and that it would be more advisable to emplace the weapons permanently on concrete mounts. Hitler accepted these ideas and suggested that 75 percent of all 88-mm guns and all 105-mm guns should be delivered in the future without guncarriages and should be permanently emplaced. In spite of vigorous protests from all military offices concerned (Air Force Command Center--General Weise; Chief AAA Officer--General von Axthelm; Branch E, AAA,--General von Renz--Office of the Chief of Special Supply and Procurement) the order was issued in March 1943 that all 105-mm and 50 percent of all 88-mm AA guns coming from the factories were to be supplied without gun carriages.

Initially, the above measure admittedly did result in an increased output of weapons, but neither material, manpower hours, nor man power were saved. On the contrary, the concrete mounts required more material than the outrigger type gun mount, and labor expenditure was merely shifted from the

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198-199 gun manufacturing processes to the building construction sector.

Apart from the above there was the fact that if and when guns had to be moved to new positions for tactical reasons, all the concrete work had to be left behind and new concrete gun mounts constructed at the new positions before the guns could be moved in. This made it impossible to bring about concentrations of antiaircraft artillery forces as required by current military situations.

These circumstances made it necessary already in May 1944 to revert to a larger output in 88-mm Model 36 AA guns with outrigger type mounts, and then it was found that the materials and personnel required for the purpose were lacking. Vlauable weapons and equipment were thus lost in both the western and eastern theaters. In some cases the troops helped themselves by making minor alterations to their searchlight mounts and then using these to transport their guns. Searchlight equipment had declined in importance since the development of radar instruments, and the troops could do without them more easily than without their guns.

The outcome was that on 5 January 1945 the demand was made for an accelerated delivery of 4,000 provisional type outrigger mounts for all permanently emplaced 88-mm AA Model 36 guns, but the war ended before these requirements could be met.

199-200 Besides the guns coming from German production, use was now also made of captured guns, as had been the case in the war of 1914-1918. The first such captured guns taken into service were the various French 75-mm calibers, such as the the M 17/34, the 36 AA Schneider/Creuzot, the AA 30 and the AA 33, and, in addition, the French 90-mm AA Model M-39 gun. The captured 83.5-mm Model 22 guns of the Czechoslovakian Army had been in use in home defense already since 1939. In 1941 the British 94-mm AA Vickers Model M-39 captured in France also came into use. After commencement of the campaign in Russia, captured Russian guns also became available, namely the 76.2-mm AA Models M-31 and M-38, and the 85-mm AA Model M-39. Most of these guns were used together with their captured fire control director equipment and where they had no such equipment they were used exclusively in barrage fire batteries. The 94-mm Vickers AA guns fired the ammunition also captured in France and only 100,000 rounds were manufactured in Germany for the purpose in 1943, since it was to be assumed that the barrels would be worn out after these stocks were exhausted.

The captured Russian material in this category comprised 96 76.2-mm AA Model M-31 guns and 192 76.2-mm and 85-mm AA Models M-38 and M-39 guns, respectively. These latter 192 weapons remained in use after the captured stock of ammunition were exhausted, the barrels being replaced

200 adapted by means of inner tubes from German production. Guns of the older Model M-31 type were scrapped as soon as the barrels became worn out since it would not have been worth while to manufacture ammunition for them and since it was not possible to adapt them by insertion of an inner 88-mm tube giving adequate performances. In the case of the other Russian guns the entire length of the barrel was rebored to take a new 88-mm Model 36 tube, but in November 1943 it was no longer possible to make the necessary manpower and factory space available even for these purposes. Finally, a workshop was equipped in Italy to do this work, where the guns were then at least provisionally adapted for German antiaircraft artillery use.

Mention must also be made here of the experiments carried out with conical tubes. Both Krupp and Rheinmetall had contracts to manufacture and test conical tubes designed to improve the performances of the 128-mm guns. To obtain better exploitation of the gaspressure and insure a more constant initial speed these barrels besides narrowing down from 128-mm to 96-mm at the muzzle were to be provided with conical springs becoming wider towards the muzzle. This was to secure a constant gas-tight closure and prevent gas pressure escaping along the sides of the shell. So far as I am informed, however, the war ended before tests with such barrels had progressed beyond the initial stages, althought they started

200-201 as early as in May 1944. There was simply a lack of designers and manufacturing space for all purposes, so that experiments of this type could make only very slow progress.

Another suggestion by an inventor merits mention here: By means of gas pressure chambers arranged along the sides of the barrel, in which small charges were to be ignited at the proper intervals, reduction of gas pressure during the passage of the missile through the tube was to be avoided and a constant gas pressure maintained throughout, thereby increasing the muzzle speed. However, the war ended before a real start could be made on this project.

AMMUNITION FOR HEAVY ANTIAIRCRAFT GUNS

Any persons who has held a responsible position in the field of ammunition supplies will be aware of how difficult those responsibilities are. Ammunition was a mass production item par excellence in the military field. It was the ammunition which was to put action into effect on the targetand one had to be able to depend on absolutely reliable manufacturing. In every occurrence of dud ammunition, ground detonation of AA shells, shell burst while in trajectory flight, or barrel bursts the reasons had to be investigated, and many a time these investigations were fruitless. The round in question had been fired and it was rarely possible to discover the cause for its failure. When a missile returned to the ground without

201-202 exploding conditions for the investigation were the easiest, since it was possible to examine the fuze and determine the actual cause. Fuze failures were a relatively frequent occurrence at the start of the war, and the general tendency was to blame the fuze manufacturers. However, investigations showed that these failures in most cases were due to wrong handling. Impact fuzes had been removed from antiaircraft ammunition already during World War I, and it was fortunate that this decision had been maintained, since shell bursts on the ground assumed considerable proportions at the beginning of World War II. One cause of fuze failures was that the fuze was inserted into the fuze setter device on a slant instead of horizontally, so that the setting cone in the fuze cylinder was damaged. It also happened that the setting cone broke off in cases in which the specified hardening process had been neglected. Furthermore, in numerous exercises at inserting the cartridge into the fuze setting cylinder the aluminium casing had been crushed, so that the setting could not take place at all. This cause was eliminated by a prohibition of exercises at fuze setting with live ammunition and furnishing the troops training shells for this purpose.

Fuze failures were particularly frequent during barrage fire, since the troops paid less heed to the detonation of the shells they fired during such action. To avoid ground detonations, which were a source of considerable uneasiness for the

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202-203 civilian population orders were issued that all fuzes were to be hand set in advance. This revealed that in some cases the waterproofing material on the fuzes had become so hardened that it was hardly possible to hand-set them. This was probably the cause for the breaking of fuze setting cones and for other discrepancies in the fuze settings. It was found that the waterproofing was particularly liable to hardening during very cold weather, and a change in this material improved matters in this respect.

In March 1942 the demand was made for an accelerated increase of AA type fuzes for 88-mm shells to 2,000,000 monthly, and by August of the year the monthly output reached the figure of 2,200,000. This made it possible to put into practice an old plan to convert to steel casings for fuzes, even if the conversion should result in a temporary drop in current output. The use of brass and aluminium for such pruposes naturally simplifies the manufacturing processes, and also makes speedier finishing of the small individual parts possible, as compared with the use of steel for these purposes. However, the shortage of raw materials made the conversion to steel casings inescapable.

It was noticed repeatedly that even in the case of reliably recorded hits with 88-mm shells, enemy aircraft were frequently still able to reach their own lines, and in some

203-204 even to return to their home bases. This brought up the question of whether it would not be advisable after all to again include a contact fuze in the shells. When this requirements was stated by Branch E (AAA) of the Chief of Special Supply and Procurement, it was rejected in mid-1943 by Office Chief Sauer in Speer's Ministry on the basis that it would not help and that it would jeopardize transport of the fuzes to the troops.

Special mention is due to Staff Technologist Voss, who was active in Air Force research and who produced scientific evidence that an impact fuze would result in a considerably increased number of planes shot down. It was only after this proof had been adduced that Speer's Ministry decided to tackle energetically the problem of the time-and-percussion fuze and finally, at the beginning of 1945, it was possible to supply to the troops ammunition with the double fuze. The increased number of planes shot down was astonishing. Although not many figures could be accurately computed before the war ended, since the output of such ammunition was still small, and although only few reliable results are available for assessment, it can nevertheless be said without exaggeration that the time-and-percussion fuze increases the chances for destruction of airplanes by antiaircraft fire threefold.

In investigation the causes for shell bursts during trajectory flight and for barrel bursts, reliance usually had to

204-205 be placed on conjecture, since the round of ammunition which was the subject of the faulty detonation was no longer available for examination. The question here was whether the faulty detonation was due to the fuze, the explosive charge, fouling of the barrel, or some other cause, and these were questions which usually remained unanswered.

As has become evident in the previous account of the types of guns in use, the chief size in use for antiaircraft purposes was the 88-mm caliber. Accordingly, 88-mm ammunition was of particular importance. Very soon after the start of the war, in 1940, the impression was gained that the ammunition was not effective enough against aircraft. In the fragmentation process at explosion, the individual fragments for the greater part had a weight of less than 5 grams each (roughly 0.15 ounce), and fragments of this size were too small to inflict considerable damage on aircraft of the structural types then in use. The fault here was that the shrapnell ammunition previously in in use by the ground artillery had simply been adopted without change, although the targets for antiaircraft fire were of an entirely different nature. In ground combat the object was to to produce the largest possible number of small fragments and thus achieve a maximum fragment density within as large a radius as possible in order to kill or otherwise incapacitate as many live targets as possible within this area. XXXX Antiaircraft

205 action, in contrast, required effect against a steel target, for which purpose the fragments had to have a certain size and weight in order to have sufficient penetrating force and a sufficiently damag//ing or destructive effect.

Prior to the war the assumption was that an 88-mm shell bursting within 33 yards of its target aircraft would be adequately effective to bring down the target. This is also the explanation for the grossly exaggerated expectations in point of the results which would be achieved against enemy aircraft. After careful investigation of the effect of the blast wave on the one hand and of the shell fragments on the other hand, it was found that it was not safe to count on an exploding 88-mm shell having an effective damaging range of more than 5.5 yards.

Attempts were thereupon made to increase the effectiveness of the exploding shell by an improved shell fragmentation and by fragmentation also of the shell base, which in the past had usually fallen in one piece to the ground, often causing considerable damage there. This was remedied by using ball-like (kugelartige) shell bases, and grooves cut into the shell casing improved the casing fragmentation. Captured Russian ammunition had been found to have grooves on the inner surface of the shell casing and investigation had shown that the size of the fragments of these shells when bursting was determined by these grooves.

205-206 For manufacturing reasons, the German shells had the grooves on the outer surface of the casing, but this also had the effect of producing larger fragments. However, it was first necessary to provide the necessary appliances to do the shell case grooving so that ammunition of this type did not reach the troops before about April 1943.

The grooves on the outer surfact of the shell casing very slightly reduced the range of the guns at very long ranges. This factor and the effects of the newly introduced iron shell rotation bands had a combined effect of reducing firing ranges by about 220 yards at distances of 9,900 yards and more. However the grooves insured a shell disintegration into uniformly sized fragments of approximately 10 grams (0.303 ounce) in weight and prevented disintegration into very small particles.

The grooving process slowed down ammunition production and in order to avoid this disadvantage experiments were made with shell casings of softer metal. Following successful results in these experiments, shell casings again were no longer grooved but made of a softer steel.

In spite of the above improvements, however, the small effect of exploding shells remained disappointing, even when the explosion took place quite close to the target.

The improved effectiveness of shells after reintroduction of the time-and-contact fuze has been discussed previously in

206-207 in the discussion of fuzes.

Recognition of the very small effectiveness of antiaircraft artillery shells resulted in all manner of experiments and the investigation of innumerable suggestions madexby inventors which quite naturally were received from all circles of the civilian population as well as from auhtorities on the subject. It would lead too far afield to discuss all of them here, but the more important suggestions investigated are mentioned below, as follows:

1. a shell which on bursting would release a parachute carrying an explosive charge suspended on as long a wire as possible, the idea being that an aircraft colliding with the wire would automatically draw the explosive charge to its body where the charge would betdetonated by a contact fuze. Experiments produded no results.

2. Shells filled with graphite were to release so much graphite in the air that the grinding effect of the graphite would damage the aircraft engines. Experiments showed that the quantities of grapgite required to produce appreciable results were so large that it would not have been possible to project them to the vicinity of the target by means of artillery shells.

3. Star shells were to be developed which would take the place of searchlights. Any such attempt would have been futile, since an aircraft would within a very short space of

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207-208 travel out of the illuminating range of any such star shell.

4. Shells containing oil or some other substance which woul[d] blind the air pilot by fouling the cockpit windows. Any such attempt could not have produced results.

5. Shells were to be fired containing spiral springs which, carried by parachutes would descend very slowly and would become entangled with and destroy aircraft propellors. Tests showed that the wire springs used did not expand but contracted instead to a lump when ejected from the shell casing.

6. Gas shells of all types were to be fired. However, it would have been impossible to obtain the necessary gas concentration.

7. Bombs were to be fired with such an intense burst glare that the air pilot would be blinded and would crash. This measure might have proved effective in individual cases and as a sudden and unexpected measure. It undoubtedly also would have had a great impact on morale. However, a remedy could have been found easily in suitable goggles.

8. Flash wire barrages were another suggestion. These were to serve as protection against low altitude air attacks and were envisaged as a start for airfields. Missiles in positions around the airfield were to be electrically released, aimed vertically upwards and carrying a wire

anchored to the ground at one end on a roller which would unwind while the missile was mounting. On bursting, the shell would release a parachute holding the wire aloft, which would descend very slowly, at about 110 yards in 1-2 seconds. It was hoped that attacking aircraft would become entangled in these wires and crash. Installations of this type were actually in use at a few airfields shortly before the end of the war. However, no records are available on the actual use of these installations, the functioning of the electrical release, and the results obtained.

9. A shell was to be developed consisting of discs, which would correspondingly disintegrate into discs upon exploding. Experiments in 1943 showed that missiles of this type had a very effective cutting action and were highly effective even at long ranges. However, mass production of ammunition of this type is not possible. A contract for the production of 25,000 such missiles for use in a trial with troops had to be withdrawn because the manufacturing facilities could not be used for this purpose simultaneously with the manufacture of another experimental type of ammunition, namely, an incendiary shrapnell shell, which will be discussed later.

10. The use of an air mine was also suggested. By ascending and descending constantly, the mine was to ob-

209 obstruct and ~~prevent~~ deny enemy aircraft an approach to the target. After exhausting its fuel supply, this "mine" was to return to the ground ~~at~~ near its original point of departure. A device to compensate for wind forces (<u>Windausgleicher</u>), combined ~~by~~ with a gyrostabilizer (Kreisel), was to prevent its drifting. The suggestion also included the possibility of remote control and remote detonation of the mine, which was to remain in the air for a maximum of five hours at altitudes between 26,400 and 33,000 feet. In August 1943 the Air Force Research Control Center under Professor Seewald received instructions to investigatethis problem. In ~~xxxxxx~~ the autumn of 1944 the factory working on this project was destroyed in an air attack and work had to cease.

11. A thin-walled shell was to contain incendiary segments of about 25 grams (about 0.76 ounce). Tests resulted in a type of missile designated as a "shell shrapnell (<u>Granat-Shrapnell</u>)"used by the Navy. However, it was impossible to manufacture shells of this type in the masses which would have been needed for general antiaircraft purposes.

12. A shrapnell shell filled with incendiaries suggested by AF Staff Technologist Voss to the AF Research Center was placed in productio at the end of 1943. However, the manufacturing processes were so complicated that it was

209-210 1944 before the first trial ammunition of this type reached the troops in the field. It was used at the Canal coast and came as a complete surprise to the enemy when planes were hit by shells bursting at a distance of 110 yards and a number were brought down. Hitler therefore called for continued production of this type of ammunition, new orders to be placed for 250,000 such shells. Unfortunately, the manufacturing processes were so difficult and time-consuming, requiring also the employment of properly familiarized personnel, that the output ratio, compared with normal shells was only one to three. The significance of this factor in view of the enormous quantities of ammunition required will become evident later in this study in the discussion of the quantities of antiaircraft ammunition manufactured. Furthermore, the new ammunition had the disadvantage that it could only be used effectively against approaching targets, since its penetration power was too small against a departing target. The velocity of the small, cylindrically shaped, incendiaries decreased very rapidly after ejection from the shell casing.

Together with the above discussion of missile development, mention must also be made of the problem of fuze setting within the gun barrel, a device under development in 1944. The object here was to reduce loading time, a highly important

210-211 factor influencing the possibilities for successful antiaircraft fire. Whereas the factors for ~~trx~~ gun traverse and elevation could be adjusted right up to the moment of firing, fuze setting had to be completed previously, at the moment the fuze was taken out of the fuze-setting mechanism. This disturbed the whole lead computation, since in the resultant time lag of three seconds the target could change its direction or by other maneuvers could upset all pre-calculations. The plan was therefore to have a device which would set the fuze while the shell was in passage through the barrel, so that adjustments could be made up to the moment it left the muzzle. This was to be achieved by means of electrical igniter mounted on the loading machanism in place of the normal fuze-setting device. An electrical impulse was then to set the fuze as it left the barrel. However, the war ended before this innovation was introduced, due to the changes which would have had to be made in the manufacture of fuzes and other processes.

The above ammunition problems have been discussed in such great detail here in order to illustrate how important the matter of increasing the effectiveness of ammunition is. Taking into consideration the fact that successful fire was guaranteed only if the shell exploded not more that 5.5 yards from its target, it must be admitted that both the guns and

211-212 and the gun crews of the German Antiaircraft Artillery performed excellently under difficult target conditions.

Besides ammunition for action against aircraft, the antiaircraft artillery also had armor piercing grenades for antitank action. Since wolfram was lacking for the manufacture of such ammunition, use had to be made of tempered steel. Antiaircraft artillery units also used hollow-charge grenades with good results in antitank action.

Thus 88-mm Model 36 AA gun batteries used the following types of ammunition against tanks:

88-mmxxx high explosive sehll with time fuze (from the end of 1944 on also with time-and-contact fuze)

88-mm AP grenades

88-mm hollow-charge shells.

A point of interest here is that from 1 September 1939 on the production target was 1,850,000 88-mm AA shells monthly. By 1 April 1940 this target was to have been raised to a monthly output of 2,346,000 shells. In the meanwhile, Hitler at the end of November 1939 because of the small consumption of AA ammunition, since no sizable air operations had occurred, and because of the shortage of ammunition for the Army's principle artillery weapon, the light field howitzer, had ordered that the production of 88-mm AA ammunition was to be reduced to 100,000 monthly until March 1940 in favor of an increased production of light field howitzer ammunition for the Army. From then on

212-213 the production of AA ammunition was again to be stepped up, as follows:

in April 1940	200,000 shells
from June 1940	400,000 "
from August 1940	1,000,000 "
from December 1940	2,000,000 "

Actual consumption in 88-mm AA shells during the period was as follows:

September 1940	1,030,000
October 1940	809,000
November 1940	551,000
December 1940	418,000
January 1941	410,000
February 1941	407,000
March 1941	474,000
April 1941	432,000
May 1941	551,000

In March 1942 the stocks of 88-mm AA ammunition had grown to such proportions that it was thought that production could again be slowed down, and it was decided to reduce the monthly output to only 1,000,000. However, it was very soon found necessary to once again increase the output.

In 1944 88-mm AA guns fired a monthly average of 1,749,300 rounds, and in October 1944, the month with the highest consumption in that year, 3,175,400 88-mm shells were fired in air defense.

For the above reason, the requirement was stated in August 1944 to establish a special program insuring an output

213-214 of at least 1,500,000 88-mm shells monthly by October, to be stepped up to a monthly output of 2,500,000 by March 1945.

Introduction of the 88-mm Model 41 AA gun with its increased performance naturally created the necessity for new ammunition. Using the old type of ammunition it would never have been possible to achieve the improved performances. A new missile with a conical lug (Zapfen) was decided upon, and a new type of low-calorific value powder was used; with the old type of nitroglycerin powder the servicable life of the barrels would have been only about 240 rounds. Even using diglokol powder the maximum barrel life would have been only 880rounds, whereas the new guanidin tubular powder insured a servicable life of 1,500 to 2,000 rounds. All barrel tests had been carried out with the brass casings still in use, but Speer's Ministry now demanded that steel casings should be used. Tests showed that casings of untempered steel could not be used in the five-section barrelnor in the four-section barrel construction tried later with an inner tube joint within the smooth part of the combustion area. The use of tempered steel was absolutely essential. Two possibilities now existed. The one was to change over to a three section or one-piece tube, the other was to use tempered steel. Saur, in Speer's Ministry, originally rejected both solutions.

It was impossible to expect the troops to put up with

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214-215 the fact that the ejector failed at practically every third round fired, so that the empty casing had to be forced out with the barrel cleaner to ready the gun for reloading. Although this defect was already known at the end of 1942, and although Branch E (AAA), Special Supply and Procurement Service, time and again stressed that this condition could not be allowed to continue, it was only at the end of 1943 that Speer's Ministry could be induced to take appropriate remedial measures. Conversion to the three-section barrel construction was to take place by March 1944. The outcome was that another 152 barrels with 5-section tubes and 133 with 4-section tubes were delivered from current production, which naturally had to use ammunition with untempered steel casings and consequently had to expect jamming troubles with the ejector. The troops simply had to put up with this disadvantage, which naturally produced numerous complaints.

Another factor here was that plans only provided for construction of the tempering ovens needed for the tempering of shell cases to render them usable with the 88-mm Model 41 AA gun in 1944. A timely improvement from this source could thus not be expected.

However, serious difficulties were also destined to arise in the matter of propellant powder. Since 1943 already the Army had insisted on an increased use of guanidin

215-216 powder for antitank weapons with high performances. The Army had also mounted 88-mm antiaircraft guns in tanks in order to exploit the excellent fire power of these guns in action against enemy tanks. Guanidin powder was naturally also needed for these guns, although it was of far greater importance for guns employed in sustained rapid fire against aircraft.

In spite of repeated urgings by the responsible military authorities, however, Speer's Ministry, which was solely responsible in the field of ammunitions production, failed to take any steps to meet the steadily mounting need for guanidin powder.

Records on conferences between Hitler and Speer reveal that both recognized that "massed antiaircraft artillery fire is successful", and when theyyboth in 1944 pressed for increased antiaircraft artillery armament the outcome of the circumstances described above was that, without regard for barrel attrition, dyglikol powder or even powders with still higher flash temperatures were to be used. This order was given in spite of the knowledge that the output in gun barrels was also inadequate. It was a clear case of self-deception, of robbing Peter to pay Paul.

In conferences during November and December 1944 the demand was made to use inferior quality powders, also for antiaircraft artillery ammunition, and at the same time

215-216 the office itself responsible in the field demanded that possibilities must be found to meet from output the mounting requirements in replacement gun barrels. However, no solution was offered to the problem of how this was to be done. Solutions similar to those adopted in World War I, in 1916-1918 were suggested, such as the addition to powder of coal dust and other materials. It was obvious that those responsible had learned nothing from the lessons of World War I and were content to wait until the last extremity before doing something to remove the bottleneck in supplies of propellant explosives. In conferences between Hitler and Speer talk even turned on whether there was no possibility of exploiting the hollow-charge effect by applying it to the shell case and the propellant charge or to the explosive charge in the shell. This shows clearly the desperate straits into which they had allowed themselves to drift, since it is quite obvious that application of the hollow charge principle presupposes conditions completely different from those found in the case of a propellant charge.

The decree issued on 4 November 1944 (Appendix 4) is extremely illuminating. That there was no possibility to meet the requirements stated there ~~xxxxxxxxxxxxxxx~~ before the end of the war is clearly obvious. It was simply impossible to remedy the omissions of the past. It seems to the point here to reiterate how many faulty decisions had been made

216-217 in the past, against which the military authorities had protested time and again, all of which had led directly to this impasse. The following are a few of these decisions:

1942: No more 88-mm Model 41 AA gun barrels were to be manufactured;

1943: Continued production of the 37-mm Model 36 AA gun was halted;

1943: Develo ent o 50-mm or 55-mm AA gun was rejected;

1941: Hitler order cessation of all long-term development projects;

1941-1943: Time and again projects for the development of guns with a heavier caliber than 128-mm and of antiaircraft ricket missiles were rejected.

Before leaving the subject of 88-mm guns and ammunition, it is necessary to discuss the serious crisis existing in respect to the 88-mm Model 36 AA gun in 1944. Early in 1944 reports suddenly arrived from the main areas of antiaircraft artillery operations (Rhein-Ruhr region, Vienna, Hamburg, Berlin, etc.) that at high altitudes antiaircraft artillery fire was approximately 220-330 yards short. Investigations were instituted immediately but brought no clarification, since the tests carried out by the proving station of Branch E (AAA) of the Special Supply and Procurement Service and simultaneously by the AAA School under instructions from the Chief AAA Officer produced completely contradictory results. The two agencies then conducted mutual investigations, in which

217-218 it was found that the shell burst point was correct as specified in the antiaircraft firing table. However, reports continued to arrive from the front concerning shorts while firing. Individual battery and battalion commanders thereupon on their own initiative introduced adjustment factors, which produced more or less improved results. One battalion in the Vienna area, for example, had unexpectedly good results in one night. The battalion commander was ordered to fly to Berlin immediately to assist in clarifying how generally valid instructions could be drafted to insure similarly good results also by other units. These conferences reminded me vividly of a case I had experienced during a peacetime firing exercise: one of the batteries with its first burst shot down a target board, repeating the feat four times in succession. Out of training considerations, the battery thereupon went over to firing with the auxiliary fire control director equipment, and its series of successes were immediately over. Reverting to use of the original director equipment and with the same gun crews, particularly with the same rangefinder operator, the batteryfailed to score another hit. With this incident in mind I greeted the battalion commander from Vienna with the words: "I congratulate you on your chance success, I am happy about that success." The gentleman was naturally badly disappointed and indignant

218 and endeavored to convince me that he had at long last recognized the error and found the way to remedy it. His opinion was that he had found the correct adjustment factor. I explained to him that his opinion could only be accepted if he returned to his unit and was able to report such good results repeatedly. Unfortunately, such reports failed to arrive. It was obvious that the solution to the problem was not so easy to find.

An officer serving in the Rheinland had applied himself intensively to this problem and since I gained the impression from the reports he submitted on his research that he was doing logically sound work I requested his immediate detachment to the AAA Branch of the Special Supply and Procurement Service, in order to work together with him in efforts to find a solution. It took more than a month to obtain the release of this officer from his front assignment for this highly important mission. Neither the Personnel Officer nor the Chief AAA Officer could prevail on the front command to send the officer to Berlin. It would have been a sound policy for the front commands to insure that the responsible agencies received the best qualified officers to solve important problems, but these front commands feared that they would lose such officers and therefore retained them in their assignments to the detriment of the entire arm. The case in point here is typical of how narrow minded the front commands were in their thought and

219 actions, and it can only be hoped that matters will be different in the future.

After the officer in question had arrived in Berlin, tests were started immediately, in which he participated. On the first day he was very optimistic and believed that he could accomplish his mission within fourteen days. After four weeks, however, he found himself compelled to report that things were by no means clear to him, since the tests showed completely different results from what he had ascertained in the Rheinland. It was only after samples of the ammunition currently in use in the Rheinland had been procured, that some light was shed on the matter. After lengthy investigations it was possible to establish the following facts, which were probably the cause of the shorts fired:

1. A shipment of powder of which samples had been tendered for acceptance had probably deteriorated after delivery had been accepted. Its average strength thereby was at the lowest limit. All shells filled with xhix powder from this shipment thus fired short.

2. In addition powder, although only a single shipment, had been erroneously weighed, due to a misunderstood telephonic message, so that all shells filled from this shipment had too low a muzzle velocity.

These findings also offered an explanation for the fact

219-220 that the complaints about short firing came only from those areas in which there had been heavy firing and which had therefore received resupplies of ammunition from new shipments.

However, it was also found in the investigations that the grooving of the shell casings and the use of iron rotation bands caused external ballistic factors which led to less accurate firing. Firing tests with the ammunition had admittedly been carried out prior to its introduction, but these had taken place during a period of bad weather, a curcumstance unavoidable under conditions of war when everything is urgent, so that it had been necessary to restrict the test firing to medium ranges. Within these ranges there had been no deflections exceeding the normal 50 percent dispersion. The failure to repeat these tests during favorable weather and at longer ranges was to have serious consequences. The firing tests now carried out showed that at distances beyond 8,800 yards short shots exceeded the permissible 50 percent dispersion ratio, shots being recorded which were 220 yards and more short of their mark. Since the units in the field with mounting frequency had to fire at targets operating at very high altitudes because their fire compelled the enemy to operate at these higher altitudes, these defects naturally only at this stage began to make themselves felt.

I have been reproached repeatedly for not having issued

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220-221 instructions prescribing the adjustment factors immediately on receipt of the first reports of short shots. I have even been asked what I would have done if I hadebeen with a field unit and had discovered these discrepancies within my command area. The only reply I could give was that I would immediately have issued orders for my command area prescribing the necessary adjustment factors. This was something that I was continuously pressed to do before I had been able to discover the precise reasons for the faulty firing.

The above matter has been discussed in great detail here because it caused much controversy at the time and also had farreaching repercussions, since it reduced the effectiveness of antiaircraft defense fire for a considerable time. The intention has also been here to show how difficult it is to determine clearly and precisely faulty performances and their causes and how wrong it is to issue standard instructions before the real causes are discovered. It is one thing to issue instructions for a circumscribed area if one believes one has discovered a fault locally, and an entirely different matter to issue general instructions valid for areas extending from Norway to Africa and from the Channel coast to the Ukraine in Soviet Russia. Instructions of this latter type must be solidly based on unquestionable facts if they are to produce really advantageous results

221-222 and not introduce new errors. The situation was finally clarified in June 1944 and the appropriate instructions could be issued to the troops.

The essential points concerning 105-mm and 128-mm AA ammunition have been discussed previously in the chapter on guns. Discussion here will therefore be limited to the types of ammunition available for these guns and the the question of ammunition consumption.

Types of ammunition for 105-mm Model 39 AA Guns:

105-mm high-explosive grenades with time fuze (from 1944 also with time and contact fuze).

105-mm AP grenades.

Types of ammunition for 128-mm AA guns:

128-mm high-explosive grenades with time fuze for AA fire or with contact fuze for fire against ground targets

128-mm AP grenades.

Average consumption in 1944 was as follows:

105-mm AA shells	199,800 per month	
128-mm " "	73,700 " "	

Largest consumption for 105-mm AA ammunition was in September 1944 with a total of 255,030 shells, and for 128-mm AA ammunition in October 1944 with a total of 102,450 shells. In August 1944 it was established that by March 1945 production was to be so increased that the monthly output would be:

105-mm AA shells	320,000
128-mm " "	130,000.

222 The question of ammunition for the guns still under development has also been discussed previously under the chapter on guns. A point which merits mention here is that a grenade-shrapnell shell was planned for the 150-mm gun. It was hoped with this caliber to obtain a better fragment spread around the detonation point.

The 240-mm gun was to have a missile with rocket propulsion in addition to the original gun velocity. The rocket propulsion was to take effect only after the missile had travelled 1,100 yards. It was to give the missile a speed of approximately 750 meter/second to the target point, which would have reduced the time of projectile flight quite considerably. Mention has been made previously of the use of proximity fuses and homing devices.

It has been mentioned previously that fatal effects could be expected from an 88-mm shells exploding within 5.5 yards of its target; in the case of the 105-mm the assumed distance was 8.8 yards, in that of the 128-mm shell 10.1-12.2 yards, and in that of the 150-mm shell 15.2 yards. In the case of the 240-mm shell it might have been safe to assume that it would have fatal effects when exploding within 22 yards of its target. Whether the blast effect of the 240-mm shell on the target aircraft could really have been improved was a matter which had to be shown in tests.

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223 In World War I, from 1914-1918, a special type of ammunition had been used for barrage fire, but no such special ammunition for this purpose was introduced in World War II. During the initial stages of the war the idea of antiaircraft barrage fire had been rejected, since no effective results were expected. However, enemy penetrations at night or protected by fog or clouds influenced the higher levels of command in the antiaircraft artillery to revert once again to barrage fire. The decision introduced certain hazards, since it created the possibility of units simply resorting to barrage fire without need, since it was so much simplerthan properly directed and aimed fire. In order to produce any results at all, barrage fire required an enormous expenditure of ammunition and also resulted in enormous barrel attrition. This was no the case when fire was governed by fire control director equipment, and the results achieved with barrage fire could only be very small in any case. How correct these assumtions were was confirmed by events and also by the reports of airmen who had operated during barrage fire. Nevertheless, the authorization to use barrage fire methods had to be given for lack of better means of defense. It is necessary to mention here, however, that cases are known in which barrage fire compelled attacking enemy planes to release their bomb loads prematurely or to divert their action to alternate targets. Bombs released

223-224 without a... were also caused by hits during barrage fire to detonate harmlessly. All of these points can be counted as advantageous results of barrage fire, even though the destruction of an enemy plane, the real object in antiaircraft fire, was rarely achieved.

Later in the war, when radar directed fire became possible the practice of barrage fire was unfortunately retained and authorized. It would undoubtedly have been possible at times to obtain better results by aimed fire.

Barrage antiaircraft fire is and will always remain nothing but a necessary evil which certain circumstances make inescapable, and should only be resorted to in such circumstances In Germany during the war, however, the less capable the troops were of handling their weapons properly the greater was their inclination to deliver barrage fire, and in this they received support in the form of recognition from the general public and from National Socialist Party offices whenever theyyhad fired a very heavy barrage, which gave the public and Party officials a false sense of security. On many an occasion the antiaircraft artillery units were censured when it was felt that they had not fired intensely enough, without any regard for whether heavy fire would have been justified or not. And how often was it found that light AA units, particularly within Germany, had wasted their ammunition in fire against

224-225 targets beyond the maximum range of their weapons, but this was something which laymen naturally could not realize.

In antiaircraft fire the missile-time-in-flight plays an immensely important role, for which reason numerous tests were naturally carried out in attempts to reduce the time-in-flight of missiles. Of these attempts only the following few will be discussedhere and that only very briefly:

Rocket problems are a metter which will have to be discussed in a separate chapter, but besides rockets, tests were also carried out with sub-caliber missiles. Particularly close attention was also given to tests with fin-stabilized missiles. With one of these missiles, 4.5 centimeters in diameter, a muzzle velocity of 1,340 meter/second had been recorded, giving a speed of roughly twelve miles in three seconds. These experiments appeared particularly promising, but the war ended before they could produce tangible results.

A variety of tests were also carried out with missiles fired from conical tubes, and in 1944 contracts were awarded to the firms of Krupp and Rheinmetall to manufacture 128-mm and 96-mm conical gun barrels.

The following brief resumé of all attempts and experiments which unfortunately could not be carried through to a finish, is offered to indicate the course pursued in efforts to achieve some progress in this field.

225-226 A 70-mm sub-caliber grenade was fired from an 88-mm Model 36 AA gun with a muzzle velocity of 1,100 meter/second. Fired from an 88-mm Model 41 AA gun the same missile had a muzzle velocity of 1,300 meter/second.

An 88-mm sub-caliber missile was fired from a 105-mm AA gun with a muzzle velocity of 1,050 meter/second.

The 45-mm fin-stabilized missile referred to previously was fired from a smooth bore tube inserted in the barrel of a 105-mm Model 39 AA gun. The exceedingly great cross-sectional pressure of the long fin-stabilized missile had the effect of insuring that the decrease in speed would be very small. In a descending curve the missile probably would have tumbled and this would have resulted in very bad scattering. For specifically antiaircraft fire purposes, however, this would have been of no significance, since in such fire action it is only the ascending curve which has to be taken into account.

Mention must also be made of experiments with "Sabot" projectiles , which commenced in 1945.

Finally, there remains the problemsof missiles with a homing nose and proximity fuzes. Solution of the problem of a proximity fuze alone would have increased the effectiveness of antiaircraft fire immensely; the problem of fuze setting would have been eliminated and there would have been no more dispersion of fire due to fuze irregularities. Develop-

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225-226 Developments of this type were called for also, and particularly so, in connection with the development of rocket weapons, but the war ended before any practicable solution could be found.

In closing this section, a compilation is offered below from which the number of rounds, calculated on the basis of experience during the war, required on an average to bring down one plane.

The assumed requirements to bring down one plane were as follows:

	Type of gun
16,000 rounds	88-mm Model 36 AA
or 8,500 "	88-mm Model 41 AA
or 6,000 "	105-mm Model 39 AA
or 3,000 "	128-mm XXXXX AA

Basing calculations on the admittedly few records available for shells with time-and-contact fuzes, the assumed ammunition consumption was

Type of gun	
88-mm Model 36 AA	5,000 rounds
or 88-mm Model 41 AA	3,000 "
or 105-mm Model 39 AA	2,000 "

Since the ammunition for 128-mm guns still had no time-and contact fuzes, no figures can be offered for this weapon.

RANGEFINDING AND FIRE CONTROL DIRECTOR EQUIPMENT FOR HEAVY ANTIAIRCRAFT GUN BATTERIES

Initially the 4-meter-base panoramic rangefinder was provided for heavy antiaircraft artillery batteries. This was a panoramic rangefinding instrument with an operating range

226-227 covering distances between 1,320 yards and 60 miles and a magnigying power of between 20 and 32. It had been introduced shortly after the start of the war to replace the 4-meter-base (Army Type) panoramic ringefinder Model 36, which covered distances between 680 yards and 30 miles and had a magnifying power of between 12 and 24.

However, the 128-mm and also the Model 41 88-mm AA guns required improved rangefinding data. The increasing altitudes at which aircraft operated also created the necessity for improved rangefinding instruments. The outcome was the 6-meter-base rangefinder, but facilities were few for the large-scale production of these instruments, and as late as in May 1944 it was only possible to turn our three per month. The only possibility to increased deliveries to six per month would have been to reduce deliveries of 4-meter-base instruments by eight per month. However, reserve stocks of these latter were also not available, so that this course could not be adopted. Initially, orders were placed for 75 of the new instruments, but plans provided for a total requirement of 500.

In August 1944 the total number of 4- and 6-meter-base rangefinder together was 3,556. These instruments were still of importance even after radar rangefinding became possible, a subject which will be discussed later in the section on radar instruments.

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227-228 Development of the computer or AA fire control director instruments continued without a break after the start of the war. During the initial stages of the war the Model 36 fire control director was adequate. Since it was only designed for speeds up to 150 meter/second, later deliveries were required t to allow for speeds up to 180 meter/second.

As related previously in the section on fire control director equipment, a new instrument had been under development since 1937 which could also provide reliable lead dat for targets in curved flight, providing, naturally, that the target curve progressed constantly during the time lag caused by data computing and transmission, loading and time of projectile flight. The target thus had to remain during this time on a course which would describe the circle the radius of which had been computed at the last focussing on the target prior to release of fire. Another requirement was that the target speed had to remain constant. In the use of this equipment the functions of the human organs, such as eyes, brain,and muscles were to a very large extent to be performed by mechanical elements, such as switches, ballistic cams, differentials, friction gears, regulators and motors. The new equipment arrived at the front units in 1940 , and it was noticable in the case of this innovation as in the case of others, that the troops only familiarized themselves with its use very slowly. The very

228-229 thorough and conscientious training they had received with the Model 36 fire control director caused them to prefer it. Antiaircraft batteries dispatched to Africa at the end of 1940 with the new equipment, for example, had to be reequipped with the old instruments. The units in question were fully familiar with the handling of the old Model 36 and might have had difficulties with the new equipment and in their distant theater of operations this might have meant that their guns would have been useless.

The new, Model 40, fire control director equipment proved excellent in field service. It could be handled by three men, compared with the 13 men required to handle the old model. Adjustment when the target suddenly changed its course was more difficult than in the old model, but this is the case in all automatically functioning devices, since they currently process the data fed to them and when changed data is fed, the new figures naturally have to go through the whole mechanism before the new factors are produced. This results in a slight lag between a change of target course and fire with readjusted aim. Given a well trained gun crew thoroughly conversant with their weapon, this lag can be adjusted by certain manipulations such as adding a slight lead or feeding adjustment factors to the instrument.

It is necessary here to stress how erroneous it was of

229 the higher command levels to assume that the mechanisms could do everything and that the antiaircraft artillery therefore no longer required especially well trained and capable personnel. This was a widespread attitude towards the antiaircraft artillery and responsible offices, such as the Personnel Office and the regional recruiting inspsctorates frequently acted accordingly. During the war it was, for example, often required of a newly activated unit or of a unit which had been required to release its trained personnel and had received completely untrained replacements that it should reproduce results equal to those of properly trained and well integrated units.

Production of the Model 40 fire control director equipment was not a simple matter, and since the output was not quite adequate, the decision was taken in September 1935 to cease production of the Model 35 and of 1-meter- and 1.25-meter-base rangefinders in order to increase the output of Model 40 equipment. The monthly output totalled 100 in July, August and September 1944, 120 in October, 135 in November, and 145 in December 1944.

In August 1944 the total numbersof fire control directors actually in use by field units were as follows:

Model 36	252
Model 35	785
Model 40	2,220.

229-230 The high-precision instruments required for data computing were equal to anything produced in foreign countries, and in the matter of their development and manufacture special mention is due, besides the manufacturing firm of Zeiss, to Colonel (Eng) Dr. Kuhlenkamp of Branch E (AAA), Office of the Chief of Special Supply and Procurement. The simple fact was that in the industries serving civilian purposes there were simply no agencies available which could have such a complete command of the scientific aspects involved that they could have been given sole responsibility for this development work. The scientific problems in tjis field are so closely interwoven wi with direct experience on the military useof the instruments and on the indispensable requirements of the troops that an outsider could not possibly acquire the familiarity and the mastery of the subject which were necessary for execution of the research and development mission. For these reasonsthe control and direction of the research and development work in this field had to remain completely in the hands of the scientific staff members of Branch E (AAA).

In 1942 work also started on the development of fire control director equipment functioning on electronic principles. Here again, special mention is due to the work done by an Air Force staff technologist, Engineer Heinz. Whereas Dr. Kuhlenkamp preferred the mechanical type of fire control equipment, 230-231 it was Heinz who advocated the advantages of electronic instruments and thus promoted the processes of development in this field of the industries. Equipment of this type was not only to bring about a simplification of the manufacturing processes, but also simplified handling procedures.

Manufacture of the fire control director required a total of only approximately 1,000 manpower hours, whereas that of the Model 40 equipment required 12,000 manpower hours. The new instruments could not go into serial production before XXX April or May 1945, and even that depended upon the necessary personnel being made available for the purpose. Since the equipment was fully automatic and required only two men for handling, the decision was taken already in mid-1944 to place orders for 1,000 of the new fire directors. The new equipment was also better suited for use in combination with radar than the former instruments had been. In spite of all these advantages and all measures taken, however, the heavy production burden on the electro industries made it impossible to manufacture the new equipment in time for use before the war ended.

The new fire control director discussed above was the first equipment which did not rely on optical orientation for its basic data. It could locate the target and find the range at distances up to 13,200 yards and functioned with polar

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231-232 coordinates. It was an angular velocity computing instrument. With its introduction the auxiliary fire control director instruments were to be withdrawn from use. It could naturally process the necessary internal and external adjustments and functioned with mechanical computing devices and used mechano-electrical selsyn motors. A mechanical silencer insured the avoidance of disturbances in the lead computations. Transmission of the computed data factors to the guns was to be by means of the usual alternating current transmitting instruments.

Another point which must be mentioned here is the development of fire control director (A3) intended for permanent emplacement at sites within Germany. In this equipment the computing elements were separate from the locating instruments and if necessary could be placed under shelter in a bunker. The locating and the computing elements were electrically connected and could function with either optical or radar orientation. The maximum operating range with optical orientation was 12 miles, with radar orientation more than 18 miles. The target position data factors were supplied to the director in rectangular coordinates; the lead factors were computed from target direction of flight and travel speed (linear method) and the mechanisms could handle horizontal speeds up to 200 meter/second, vertical speeds up to 100 meter/second, and could compute the

232-233 traverse lead up to 5,500 yards. Ballistic adjustments naturally also had to be processed. The entire apparatus was fully automatic. Four men were required to make adjustments for target course deviations, changes of horizontal speed, of vertical speed, and changes of direction. The computing mechanisms functioned automatically; the selsyn motors used mechano-electrical amplifiers. Position differences could be corrected up to distances of 12 miles, so that the equipment could furnish the firing data to far distant batteries.

Whenever possible captured weapons were used together with their original captured fire control director equipment, and the following types of such equipment were so used:

French OPL Model 37 fire control director equipment
" Aufière Model 32/39 Fire control director equipment
" Précision Moderne " 36 " " " "
Russian Model Puaso " " " "
Wikig Model 9 SH " " " "

Not to be forgotten here are the many various types of data conversion devices made by the troops themselves to make use of the firing data factors obtained from other battery positions when the lack of fire control director equipment, or other causes such as the inability to locate the target from their own positions because of conditions of dark, fog, etc., made it impossible for them to obtain their own firing data.

233 For such purposes the battery concerned had to determine on a battery plan the lateral angle for its own battery position and to do so it had to have the elevation angle and the range data of the other battery and from this data calculate the elevation angle and range data for its own guns. Because of target travel speeds and changes of direction this data conversion naturally had to be done without delay, since otherwise the data would have been valueless. The experience gained by the troops and the work they did in this field were all evaluated and finally incorporated in the AAA Data Converter "Malsi introduced for general use in 1942. This new instrument was to attain special importance later, after introduction of the improved radar instrument, since it could then even be used for fire control.

SEARCHLIGHTS AND SOUND LOCATORS

The 60 centimeter AA searchlight model remained in use in combination with automatic AA weapons up to the end of the war, since its relatively small illuminating range with its 150-million Haefner Candle power beam was adequate for the short effective firing range of these weapons. It was manufactured by the firm of SSW and was transportable on Special Type trailer Model 60. Development of a new and improved lamp with simplified manufacturing processes was completed in 19

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253-234 in 1944.

At the beginning of 1942 the production of 60-centimeter searchlights was reduced to 60 per month, but in October of the same year already, a monthly delivery of 220 was demanded, and even as late as in October 1943 Hitler insisted on a minimum monthly production of 200 searchlights. Production was to switch over to the new type of 60-centimeter searchlight in August, with a projected monthly output of 200. In actual fact, however, only the following numbers of the new model were ever delivered:

July 100, August 120, September 140.

In August 1944 the following searchlights were in service

60-centimeter AA Type Searchlights (mobile)	3,582
60- " " " " (permanently emplaced)	794.

The 150 centimeter Model 37 searchlight introduced at the start of the war in 1939 with a beam of 1.1 billion Haefner candle power soon proved inadequate against aircraft operating at steadily mounting altitudes. For this reason projects were under way in the firms of AEG and SSW soon after the outbreak of war to construct a 200-centimeter searchlight. Both firms submitted their trial models already in 1940.

In October 1942 the demand was made for monthly deliveries of 200 ~~XX~~ 150-centimeter and 100 200-centimeter AA searchlights. Copper shortages made it impossible to meet such requirements.

234-235 Enormous quantities of copper were needed in particular for the current transmission cables and for the armature winding. The question was therefore raised of permanently emplacing at least 50 percent of all searchlights and linking them to local power circuits in order to save copper and power fuels. This naturally reduced flexibility in operations, but that was not such an important consideration in searchlight operations.

Since the output of 200-centimeter AA searchlights increased only very slowly, use was made of four searchlights on a quadruple mount. Afew of these mounts were placed in service in 1943, but they were also difficult to manufacture and their performances were inferior to those of a single 200-centimeter searchlight.

The 200-centimeter High-Performance searchlight (Photo 109) reached the front units in mid-1943. With an illuminating power of 2.7 billion Haefner candles this searchlight could pick up and hold a target at distances between 13,200 and 14,300 yards. It, or the quadruple-mounted 150-centimeter searchlight, was used as the master or pick-up searchlight in the searchlight platoon of 3 searchlights, and it was usually used in combination with a radio locator.

For effective support of the antiaircraft artillery, all searchlights had to be stationed 4-6 miles forward of the heavy gun batteries. This was the only way to insure

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235-236 the maximum effectiveness of antiaircraft fire. This explains the large numbers of searchlights needed for really effective results.

The use of searchlights in night fighter defense operations also played a very important role as long as electrically functioning target detecting instruments were not available for aircraft etc. Along the main routes of approach to the Rhine region and Berlin night fighter zones, with heavy searchlight support, had therefore been established forward of the antiaircraft artillery defense zones. In order to avoid having these searchlight units lying idle on nights when weather conditions precluded the possibility of air/defense operatings, plans provided for the commitment of AA super-batteries in these areas. It was here that the idea of an AA super battery evolved and was first put into practice. The super-battery consisted of three batteries combined and linked with a fire control director controlled by a radar instrument. It was Lieutenant General ~~KAMMMMMMXX~~ (General der Flieger) Kammhuber who recognized this possibility and put it into practice. The first such unit started operating in 1940 and later formed the basis for the development of other super-batteries. Plans provided for a gradual cessation of the production of 150-centimeter serachlights in October 1943, from when on only 200-centimeter searchlights were to be manufactured at the reats 8f 400 monthl .

236-237 At the same time a project for development of a 300-centimeter searchlight was rejected. In August 1944 Hitler demanded that the monthly output of 200-centimeter searchlights be stepped up to 400. Actual monthly deliveries in 1944, however, were approximately as follows:

150-centimeter AA searchlights	290
150- " " " on quadruple mounts	5
200-centimeter searchlights	190

The following were in service with front line units in August 1944:

150-centimeter AA searchlights (mobile)	5,675
150- " " " (Permanently emplaced)	1,636
150- " " " (on quadruple mounts)	61
200-centimeter searchlights	2,262

In 1944 introduction of a 500-Ampere burner-cavity (Brenn-Kammer) lamp from the firm of AEG improved the illuminating power of the 200-centimeter searchlight. Five of these new lamps were in use before the end of 1944.

Very important XXXXXXXX development work was also done in the field of electric lighting carbon, but this can only be mentioned incidentally here. Searchlight reflectors also required considerable development and research work, but mention need only be made here of the use of centrifugally cast glass reflectors and the practice of only plating the top surface.