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TECHNICAL REPORT No. 347-45

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GERMAN AIRCRAFT GUNS AND SPECIAL WEAPONS

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TECHNICAL REPORT No. 347-45

GERMAN AIRCRAFT GUNS AND SPECIAL WEAPONS

SUMMARY

This report presents an outline of and data concerning the work of the Automatic Weapons Section, Rheinmetall-Borsig A.G., Unterluss, Germany.

September 1945

U. S. NAVAL TECHNICAL MISSION IN EUROPE

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NOTE: All dimensions in Figures are in millimeters.

GERMAN AIRCRAFT GUNS AND SPECIAL WEAPONS

1. Introduction.

The Rheinmetall-Borsig Company can be considered as the leading aircraft gun designer of Germany. Perhaps the only other firm that even approached this company was the Mauser company. However, the majority of aircraft guns in German aircraft were made by Rheinmetall-Borsig. The Automatic Weapons Section, headed by Mr. Fritz Herlach, was a tightly knit organization, the key members of which had worked together for 18 years. This group took great pride in their work and were more than anxious to "tell all". It can be reliably assumed that this report is a comparatively complete and accurate outline of German aircraft gun development as reflected by Rheinmetall-Borsig. Other reports concerning the work of this company in connection with aircraft rockets, gun turrets, and remotely controlled gun mounts are being prepared.

It should be noted that the term "MK" as used by the Germans, refers to "Maschinen-Kanone" or automatic cannon, rather than to "Mark", as in the United States or England. Similarly, the term "BK" means "Bord Kanone", an expression difficult to translate but meaning, essentially, an airborne cannon.

Samples of most of the service weapons have been shipped to the United States in instances where large quantities were available. The new MK 112 5.5 cm. cannon was, unfortunately, not found in sufficient quantity. It is believed that two of these cannons were evacuated to England for tests, and that unfinished parts for one other were evacuated by U. S. Army personnel.

2. MK 112 Gun (5.5 cm.)

(a) Design and Operation.

Evolution. The Ordnance Bureau of the Air Ministry set up the following requirements for the development of an automatic aircraft cannon: Caliber 5.5 cm., initial velocity 600 m/s; shell weight 1.5 kg.; explosive charge at least 0.4 kg.; cyclic rate at least 300 rounds per min.; no alloyed steels to be used; simplest manufacturing procedure; electric firing; remote control; possibility of use as flexible, fixed and engine mounted gun. Because of satisfactory results with the 3 cm.

2. MK 112 Gun (5.5 cm.) (a) (Cont'd.)

MK 108, the mass-bolt (Massenverriegelung) system was chosen as the gun system for the MK 112. Thus, the whole construction of the gun was made quite rugged and the individual parts could be made to have quite long life, considering the low grade of material used.

The main parts, such as gun housing and feed, were made as sheet metal stampings. Low cost manufacture for mass production was made possible by welding attachment lugs and guide rails. In order to keep the recoil within practical limits, the gun was equipped with a recoil mechanism. The counter-recoil, occurring when the bolt returned to the forward position, was also absorbed by the recoil mechanism.

Two samples of this gun were taken to England for test and the parts for a third gun were taken to the United States by Army investigators. No other samples are believed to be in existence. Complete reports concerning the design of this gun were prepared by ADIK and copies may be obtained through the Naval Air Attache's office in London if desired. A description of this gun is being included herein to supplement the reports already written.

Description (see Figure 1): The gun consists of: (1) the barrel including buffer; (2) gun housing with electric firing leads; (3) bolt with electric firing and buffer; (4) bolt recuperator mechanism; (5) feed; (6) electro-pneumatic charging device; (7) electro-pneumatic trigger; (8) base plate; (9) electric switch contacts; (10) cartridge belt.

The barrel (monobloc gun barrel) is mounted in the front gun housing so as to be moveable against a buffer spring. The gun buffer, consisting of a coil spring, lies in a casing around the front end of the barrel. A lug is attached to the casing for mounting the gun in the mount. The gun buffer is attached to the barrel by a threaded ring. At the back end of the buffer is the buffer piece which limits the forward movement of the bolt.

The gun housing, containing the movable and fixed working parts, is made of stamped sheet metal. The bolt slide rails are stamped into the gun housing and are not machined. On the upper side of the gun housing are the lugs for the knuckle bolts of the feed housing, and be-

2. MK 112 Gun (5.5 cm.) (a) (Cont'd.)

hind the opening for the feed are the lugs for the attachment of the feed housing. On the upper rear part of the gun housing are the mounting lugs for the electro-pneumatic trigger. At the back of the housing are the lugs for mounting the base plate. The piston of the bolt charging device is fastened in the frontal plate, which device has a packed joint for attaching the air line. The electric switch contact is fastened on the gun housing outside and underneath the bolt guides.

The bolt is a one-piece forging. The frontal side of the bolt is fitted with a removable hardened steel liner, which is put in with a bayonet lock and then pinned. On the upper side, are the lugs for mounting the extractor which is operated by helical thrust springs. The electric firing pin is housed in a longitudinal boring and its current feed is brought out the left side of the bolt. There are lugs on the under side of the bolt for mounting the bolt buffer. The bolt springs are built-up columns of coil springs (Ringfedersaeulen) that stick out behind the bolt with a buffer piece. Underneath the front end are the lugs for mounting the bolt recuperator springs. On the upper flat side of the bolt, at the back, are the faces against which the trigger catches, and on the right and left are the transport slides that run from front to back.

The bolt recuperator consists of two columns of springs of four compounded and overlaid spiral compression springs each. The springs are pre-compressed when installed in their housings.

The feed housing is made of pressed metal parts. In it are the two transport curves which move in opposite directions and the feed catch (pawl) and retaining catch. The transport curves are connected to the two transport levers that are in the feed housing and which run into the bolt. In the feed housing are also the curves (cams) for controlling the transport pawls. The feed is fastened to the front end of the gun housing and is connected to it by a "speed connector" which is loosened by hand.

The charging piston is screwed into the front wall of the gun housing. A charging cylinder is mounted around the piston so that it can move longitudinally. A spiral compression spring which bears against the back plate, is used to recuperate the charging cylinder.

2. MK 112 Gun (5.5 cm.) (a) (Cont'd.).

The electro-pneumatic trigger is mounted in the rear gun housing so as to be movable lengthwise against two coil springs which act as buffers to take up the shocks of catching the bolt each time. In the trigger housing are the trigger bar, which catches the bolt, and the air-operated piston that controls it.

The base plate closes the back of the gun housing and is fastened to it by bolts with a bayonet-locking type of action. It serves to limit the maximum recoil of the bolt and also as a counter bearing for the springs of the bolt recuperator and bolt charging devices.

The switch contact is made of a sheet metal stamping and is bolted to the gun housing. A firing stud, inside the switch contact, projects into the gun housing and carries current for the electric detonator when it passes over the bolt contact. In order to carry out the charging of the bolt automatically, in case of a failure to fire, there is a switch lever on the back part of the switch contact that is activated by the bolt.

The cartridge belt is made of sheet metal stampings of carbon steel which are made in the form of hooks and eyes. The individual disintegration is controlled by the shell, which holds the belt together. After the empty is pulled, the belt comes apart. At front and back are the belt bearing surfaces needed for the belt feed and on the back end, right and left, there is hooks to hold the ammunition.

Operation: The gun system is built as a "mass-bolt" system (Massenverriegulngssystem). When the electro-pneumatic trigger is pulled, the bolt moves forward under the pressure of the bolt recuperator springs and thus activates the feed by means of the transport curves milled into the body of the bolt and corresponding levers mounted in the feed. This moves the belt halfway into position until the bolt head strikes the base of the shell and then moves it into the middle. As the bolt moves on forward, the shell, now standing in the middle, is pushed out of the belt, and the extractor, which has been pushed upward, drops down behind the rim of the case. The shell, held firmly by the extractor, is then pushed into the chamber of the barrel by the bolt.

The electric firing of the shell takes place at just the right time

2. MK 112 Gun (5.5 cm.) (a) (Cont'd.)

so that the bolt can be turned before it has reached the dead end of its forward movement. The resulting gas pressure forces the bolt back over the base of the shell case. The case is pulled back into the belt section by the extractor hook as far as a stop built into the gun housing. Just before end of travel, the extractor hook is forced away. As the bolt moves on back, the transport curves (cams) cause the belt to be fed into the middle of the gun. When this has occurred, the remaining bolt energy is taken up by a bolt buffer built into the bolt itself, which bears against the gun housing. If the electro-pneumatic trigger is no longer activated, the bolt is caught by the trigger after a short movement forward. If the shell did not fire, the bolt counter-recoil is taken up by the gun buffer.

By activating the electro-pneumatic bolt charging device, the bolt is shoved back of the trigger bar by the air charging cylinder. The air charging cylinder is then returned to its former forward position by a coil compression spring. The shell feed is managed with a disintegrating belt from the left or right. The discharge of the shell links and cases occurs singly on the opposite side from the feed.

Assessment. Altogether, 10 guns were built, of which 7 were an older model with about 300 kg. weight and 3 newer models with 275 kg. weight. Five other guns of the newer model were under construction.

Firing tests were made with the 7 earlier model guns to test the function of the various units. One gun was loaded with 1300 rounds. Tests were made at from -15° to plus 70° elevation. The gun didn't function perfectly at high elevation, nor did the belt demonstrate satisfactory function and durability in these tests. The required cyclic rate of 1300 rounds per min. was met, even with the required belt lift of 2 meters. Bursts of from 5 to 20 rounds were fired. Attempts to increase the cyclic rate got it up to 360 rounds per min. but the belt was not quite strong enough so that a cyclic rate of 300 rounds per min. was established as maximum.

Experiments were begun in a cold chamber at -50° but sufficient data worth evaluating had not yet been gathered. The function and durability of various parts of the gun were not entirely satisfactory. These short tests also showed that the carbon steel used for many parts was not satisfactory and that considerable structural changes were necessary.

2. MK 112 Gun (5.5 cm.) (a) (Cont'd.)

In all experiments, there were difficulties in the electrical system for firing at the firing pin and in the transmission elements from the switch contact to the firing pin. There was also trouble in the belt feed caused by the insufficient durability of the belt. A hydraulic charging device was being designed to replace the air charging device.

No experimental installations in airplanes had yet been made.

Altogether 600 rounds were fired with one of the new model guns. These rounds were fired to study operation, reliability, and belt pull, especially when the gun was elevated. The previously mentioned troubles with the electric circuit and the belt itself occurred in these later tests also. Hot and cold tests had not been carried out with this newer type gun.

(b) Functioning Computations.

i. Data for calculating the functioning of the gun.

Weight.

Breech mechanism, G_1

Breech alone......................	60.0 Kg.	132#
Breech parts which recoil.......	5.0 Kg.	11#
Shell..............................	2.4 Kg.	5.28#
Weight of breech while moving forward. G_{1V}	67.4 Kg.	148.28#
Empty case.........................	0.65 Kg.	
Weight of Breech in recoil....G_{1R}	65.70 Kg.	

Barrel, G_2

Barrel alone......................	40.0 Kg.
Barrel parts which recoil........	5.0 Kg.
G_2	45.0 Kg.

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Gun housing................	G_3	155.0 Kg.
Case for the mount........	G_4	10.0 Kg.

Designation	Mass	Kg m^{-1} s^2
Mass of forward moving breech	M_{IV}	6.86
Mass of recoiling breech	M_{IR}	6.7
Mass of entire barrel	M_2	4.59
Mass of gun housing	M_3	15.8

Paths of movement in operation (Fig. 2)

Breech mechanism, from stop on front of housing to:

Catch position (locked open)	600 mm.	
Contact with buffers	640 mm.	
Stop on rear of housing	700 mm.	
Point where electric detonator contact takes place.	60 mm.	

Barrel

Total recoil with respect to mount casing	60 mm.	2".362
Total counter recoil with respect to mount casing	60 mm.	

Gun Housing.

Housing recoil with respect to barrel	20 mm.	."8
Max. recoil with respect to mount casing	30 mm.	
Counter recoil with respect to barrel	0	
Counter recoil with respect to mount casing	60 mm.	

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Main operating springs. ....

Closing and breech buffer spring (See Fig. 3).

The closing spring is comprised of 7 springs, each with 17-22 Kg. initial tension and 80 ± 10 Kg. final tension.

Then, let:

P_v : 7 x 18 : 126 Kg.
P_e : 7 x 80 : 560 Kg. (in the catch position S:600 mm.)
P : f (s)
s : Path of spring movement.

Spring constant

$$C : \frac{560 - 126}{600} : \frac{434}{600} : 0.724 \text{ Kg/mm.}$$

Energy absorption of the spring during recoil of breech, A_{SR}

$$A_{SR} : \frac{R + P}{2} \times s$$

For the buffer spring

$$A_{PR} : \frac{P_v + P}{2} \times s$$

During counter recoil

$$A_{PV} : 0.35\, A_{PR}$$

Elasticities and work capacity of the closing spring.

S	C x S	P	Pv + P	A_{SR}	A_{SV}
mm	Kg	Kg		Kgm	Kgm

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Elasticities and work capacity of the closing spring. (Cont'd.)

S	C x S	P	Pv + P	A_{SR}	A_{SV}
0	0	126	126	0	0
200	144.8	271	199	39.7	13.9
400	289.6	416	271	108.4	38
600	434.4	560	343	205.8	72
640	463.0	589	358	229	80
700	506.8	633	379	265	93

The buffer spring begins to act as Pv : 1000 Kg. and Pe : 10000 Kg and overlaps the movement of the closing spring in the range S : 640... ...700 mm. so that the combined spring strength has the following characteristics:

$$P_V : 589 + 1000 : 1589 \text{ Kg.}$$
$$P_e : 633 + 10000 : 10633 \text{ Kg.}$$
$$C : \frac{10633 - 1589}{60} : 151 \text{ Kg/mm.}$$

Elasticities and work capacity of the combined springs.

S	S	C x S	P	Aps	Apr	Apv
mm	mm	Kg	Kg	Kgm	Kgm	Kgm
640	0	0	1589	0	229	30
650	10	1510	2100	23.5	253	88.5
660	20	3020	4610	62.0	291	102
670	30	4530	6120	115.5	345	121
680	40	6040	7630	184.4	413	145
690	50	7550	9140	268.0	497	174
700	60	9060	10650	367.2	596	208

Barrel - Mount casing spring (see Figure 4)

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

$$C : \frac{5000 - 1000}{60} : 66.7 \text{ Kg/mm}$$

Barrel - housing spring (See Figure 4)

$$C : \frac{5000 - 1000}{20} : 200 \text{ Kg/mm}$$

Gun impulse.

The gun impulse Iw is composed of two parts:

The impulse I_1 of the mass of the shell and propulsion charge.
The after-effect impulse I_n of the powder gases after the shell leaves the muzzle.

Hence:

$$Iw : I_1 + I_n$$

$$I_1 : \frac{G_G + 0.5\ G_L}{g} \times Vo : 1.48 + \frac{0.5 \times 0.215}{9.81} \times 600 : 97 \text{ Kgs.}$$

$$I_n : \frac{Pa \times V}{a} : \frac{610 \times 24.5 \times 100}{1000 \times 10^2} : 15 \text{ Kgs.}$$

Pa : muzzle gas pressure according to Heydenreich.

V : 1000 Ms^{-1} (empirical factor)

Iw : 97 + 15 : 112 Kgs.

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Breech impulse at the end of forward movement from the catch position.

Forward energy of the closing spring from catch position (S:600 mm)

$$E_F : 80 \text{ Kgm.}$$

Energy of the closing spring at the forward reversing point.

$$E_U : 3 \text{ Kgm.}$$

Kinetic energy in the breech mechanism during forward movement.

$$E_V : E_F - E_U : 80 - 3 : 77 \text{ kgm}$$

$$E_V : \frac{M_1V}{2} x V_V^2$$

Then it follows that:

$$V_V : \frac{2Ev}{m_1V} : \frac{2 x 77}{6.86} : 22.4 : 4.73 \text{ m/s}$$

Breech impulse at the end of forward movement from the catch positions.

$$I : M_{1V} x V_V : 6.86 x 4.73 : 32.5 \text{ Kgs.}$$

Breech recoil velocity at start of recoil.

The gun impulse : breech counter recoil impulse + breech recoil impulse.

$$Iw : I_V + I_R$$

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Any calculations between the shell case and the chamber while the gas pressure is exerting its effect can be disregarded if the cases are well oiled, as has been proven by many tests.

Hence: $I_R : I_W - I_V$: 112 - 32.5 : 79.5 Kgs.

Therefore, the velocity of breech recoil is:

$$V_R : \frac{IR}{m_{IR}} : \frac{79.5}{6.7} : 11.9 \text{ m/s}$$

and the kinetic energy of the breech mechanism at beginning of recoil is:

$$E_R : M_{IR} \times \frac{Vr^2}{2} : 5.7 \times \frac{11.9^2}{2} : 475 \text{ Kgm.}$$

ii. Displacement-Time Curves for Breech Mechanism.

From the position S : 35 mm. before the forward end position, the breech recoils at a rate of:

V_{RA} : 11.9 m/s (back)

Length of time Ta until it strikes the buffer (Point C, Fig. 3)
Spring energy at Point C, E_C : 229 Kgm.
Spring energy at Point A, E_Q : 3 Kgm. (appr.)
Energy absorption by the breech mechanism:

$$E : E_C - E_A : 226 \text{ kgm.}$$

Kinetic energy of the breech mechanism at Point C.:

$$E_{VC} : E_R - E : 475 - 226 : 249 \text{ Kgm.}$$

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Velocity:

$$V_{RC} : \frac{2E_{VC}}{M_{IR}} : \frac{2 \times 249}{6.7} : 8.6 \text{ m/s}$$

Mean velocity:

$$Vm : \frac{Vra + Vrc}{2} : \frac{11.9 + 8.6}{2} : 10.3 \text{ m/s}$$

Time:

$$Te : \frac{S}{Vm} : \frac{0.64 - 0.035}{10.5} : 0.0588 \text{ s.}$$

Time T_b from the start of the buffer action to the point where the breech mechanism reverses its direction (see Fig. 5). In order to get an approximate solution, the gun housing is assumed to be rigid:

$$tgwt_b : \frac{VRC \times C}{P_c \times w}$$

$$c : 151 \text{ kg/mm} : 151000 \text{ kg/m.}$$

$$w : \frac{c}{m} : \frac{151000}{6.7} : 150 \; S^{-1}$$

$$P_c : 1589$$

$$V_{RC} : 8.6 \text{ m/s}$$

$$tgwt_b : \frac{8.6 \times 151 \times 10^3}{1589 \times 150} : 5.45$$

$$wt_b : 79.6^\circ : 1.39$$

$$tb : \frac{1.39}{150} : 0.0093 \text{ s}$$

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Time (t_c) from the rear-most point where the breech mechanism reverses its motion to the end of the buffer effect: the spring force (of the buffer spring) when expanded, is about 0.35 times the force when compressed. Figure 3 was prepared on this basis. Then:

$$W^1 t_c : wt_b$$

$$Tc : \frac{wtb}{w^1} : \frac{tb}{0.35} : \frac{0.0093}{0.592}$$

Time from the end of the buffer effect to the front bolt reversing point:

According to Figure 3, the energy at the end of the buffer, E : 87 kgm.

Hence the velocity of the breech mechanism is:

$$VE : \frac{2 \times E}{m_{IR}} : \frac{2 \times 87}{6.7} : 5.1 \text{ m/s}$$

The energy of the breech mechanism at the end of counter recoil is:

$$E_V : 0.35 \times E_R : 0.35 \times 475 : 166 \text{ kgm.}$$

At this point the breech mechanism has a mass of:

$$m_{IV} : 6.06 \text{ kgm}^{-1}\text{s}^2$$

And the maximum counter recoil velocity is:

$$V_V : \frac{2\ Ev}{m_{IV}} : \frac{2 \times 166}{6.86} : 6.96 \text{ m/s.}$$

The mean counter recoil velocity is:

$$V_m : \frac{V_{VE} + V_V}{2} : 6.03 \text{ m/s.}$$

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

The counter recoil distance at a reversing point S : 35 mm. from the forward stop on the housing is:

$$S : 640 - 35 : 605 \text{ mm.} : 0.605 \text{ m}$$

and the time becomes:

$$t_d : \frac{0.605}{6.03} : 0.1002 \text{ s.}$$

Recoil velocity after the second shot:

The recoil impulse of the breech mechanism after the second shot becomes:

$$I_R : I_W - I_v$$

$$I_W : 112 \text{ kgs.}$$

$$I_v : m_{IV} \times V_v : 6.86 \times 6.96 : 47.7 \text{ kgs.}$$

$$I_R : 112 - 47.7 : 64.3 \text{ Kgs.}$$

Hence the recoil velocity V_r is as follows, when m_{IR} : 6.7 $Kgm^{-1}s^2$:

$$V_R : \frac{I_R}{m_{IR}} : \frac{64.3}{6.7} : 9.6 \text{ m/s}$$

The space time curve of the breech mechanism relative to the housing is shown on Figure 5. The curve is an approximation since it was assumed that the gun housing was rigidly fixed.

The number of rounds that may be fixed per minute can be computed:

$$T : t_a + t_b + t_c + t_d : 0.0588 + 0.009 + 0.1002 + 0.0157$$
$$T : 0.184 \text{ s.}$$

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

Hence the cyclic rate:

$$n : \frac{60}{0.184} : 324 \text{ min.}^{-1}$$

iii. Force of Recoil.

The exact movements of the breech mechanism, housing and barrel were carefully computed by analyzing the total motion. These computations were destroyed during the last part of the war and it is therefore necessary to present, herein, an approximate calculation of the recoil force.

The gun impulse amounts to:

$$I_W : 112 \text{ kgs.}$$

The gun weight, concentrated at the center of gravity is:

$$G_W : 275 \text{ kgs.}$$

From this, the recoil velocity of the center of gravity is:

$$V : \frac{I_W}{G_W} \times g : \frac{112}{275} \times 9.81 : 3.85 \text{ m/s}$$

The recoil energy is:

$$E : \frac{G_W}{g} \times \frac{V^2}{2} : \frac{275}{9.81} \times \frac{3.85^2}{2} : 207 \text{ kgm.}$$

According to the energy curve, Fig. 4., the energy absorption of 207 kgm corresponds to a recoil distance of the housing, of 73 mm. The spring curve shows, for this distance, a force of:

$$R : 4700 \text{ kg.}$$

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

iv. Time required for the shot to fire.

The breech mechanism, while moving forward, closes the firing contact 60 mm. before reaching the stop on the housing. The forward or counter recoil velocity of the breech mechanism at this point: $V_V : 7$ m/s. At this velocity, the breech mechanism would reach the front stop after t: $\frac{0.06}{7}$: 0.0086 seconds. Hence the shot development time must be kept less than 0.0086 seconds.

v. Increasing the number of rounds per minute.

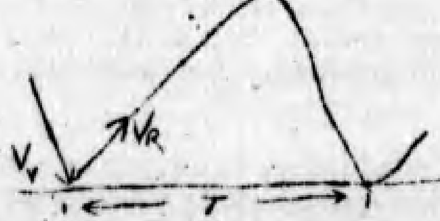
By reducing the weight of the breech mechanism but keeping the general overall dimensions the same, it is possible to increase the rate of fire.

The firing impulse, I_W, remains constant.

And $I_W : m\ V_R + V_V$

(In this study, the breech mass in recoil and counter recoil are considered as being the same.)

In the sketch herewith, as the mass becomes smaller, the velocity V_R and V_V increase. The time, T, varies inversely with V_R and V_V for the interval of one round.



Path of Breech Mechanism

Hence, it follows that as the mass, m, of the breech mechanism becomes smaller, the time T becomes less, i.e.:

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

$\frac{m^1}{m} : \frac{T^1}{T}$ and the no. of rounds per min., n, is:

$\frac{n^1}{n} : \frac{T}{T^1} : \frac{m}{m^1}$, from which it follows that:

$N^1 : \frac{m}{m^1} \times n : \frac{G}{G^1} \times n$.

Assuming that n : 300 rounds per min., and a weight for the breech mechanism of G_1 : 60 kg., the cyclic rates, n^1, for the weights, G'_1, may be seen from the table:

$\frac{G_1}{G'_1}$	G^1 Kg	n spm.	Vr m/s	A compressed Kgm
1.0	63	300	11.9	456
1.2	52.5	360	14.2	535
1.33	47	400	15.9	606
1.4	45	420	16.5	626
1.5	42	450	17.8	678

The possible increase of the cyclic rate per minute shown here has its practical limits. The initial velocity, V_R, with which the breech mechanism recoils after the shot, increases. Keeping in mind a long life for the closing springs, this velocity V_R must be kept below the limits of 15 to 18 m/s if possible, because the springs otherwise collapse very soon (become fatigued). Other difficulties, such as belt feed troubles, also arise with too high cyclic rates.

The initial velocity, V_R of the breech mechanism should be computed approximately as follows:

$$I_W : m \times V_R + m \times V_V : I_R + I_V$$

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

If it is assumed that the damping properties of the springs remain the same, that is, that the overlaid closing springs, when expanded, only offer 35% of the force that they absorb when compressed, then at each point in the movement of the spring the force during the forward movement of the breech mechanism is $P_V : 0.35\ P_R$.

P_R : force during recoil.

Then the energy absorption of the springs is in the same ratio as the force:

$A_{EX} : 0.35\ A\ comp.$

A_{EX} : energy absorption upon expansion of the spring.

A comp. : energy absorption upon compression of the spring.

Then $A_{EX} : \frac{m}{2} V_V^2$ and $A\ comp. : \frac{m}{2} V_R^2$

or: $V_V : \frac{2\ Aex}{m} : \frac{2 \times 0.35}{m}\ A\ comp.$

$V_R : \frac{2\ A\ comp.}{m}$

Consequently: $\frac{V_R}{V_V} : \frac{1}{0.35}$ and $V_V : V_R \times 0.35$

Substituting in the impulse equation, above:

$$Iw : m \times Vr + m\ Vr\ 0.35 : m\ Vr\ (1 + 0.35)$$

and $Vr : \frac{Iw}{m \times (1 + 0.35)}$

if Iw : 112 kgs.

2. MK 112 Gun (5.5 cm.) (b) (Cont'd.)

then $$V_r : \frac{112}{1.592 \times m} : \frac{73.0}{m} : \frac{73.0}{G_1} \times g$$

The values of V_R are also calculated in the foregoing table.

As can readily be seen, the energy to be absorbed by the closing spring and the breech mechanism spring, together, changes according to the velocity of recoil.

$$A \text{ comp.} : \frac{m}{2} \times V_R^2$$

The energy values have also been entered in the table above.

The energy, which has to be absorbed by the springs, increases proportionally with the cyclic rate.

Figure 6 represents the number of rounds per minute, n, dependent upon the mass of the breech mechanism, m. In addition, the breech recoil velocity V_R is indicated.

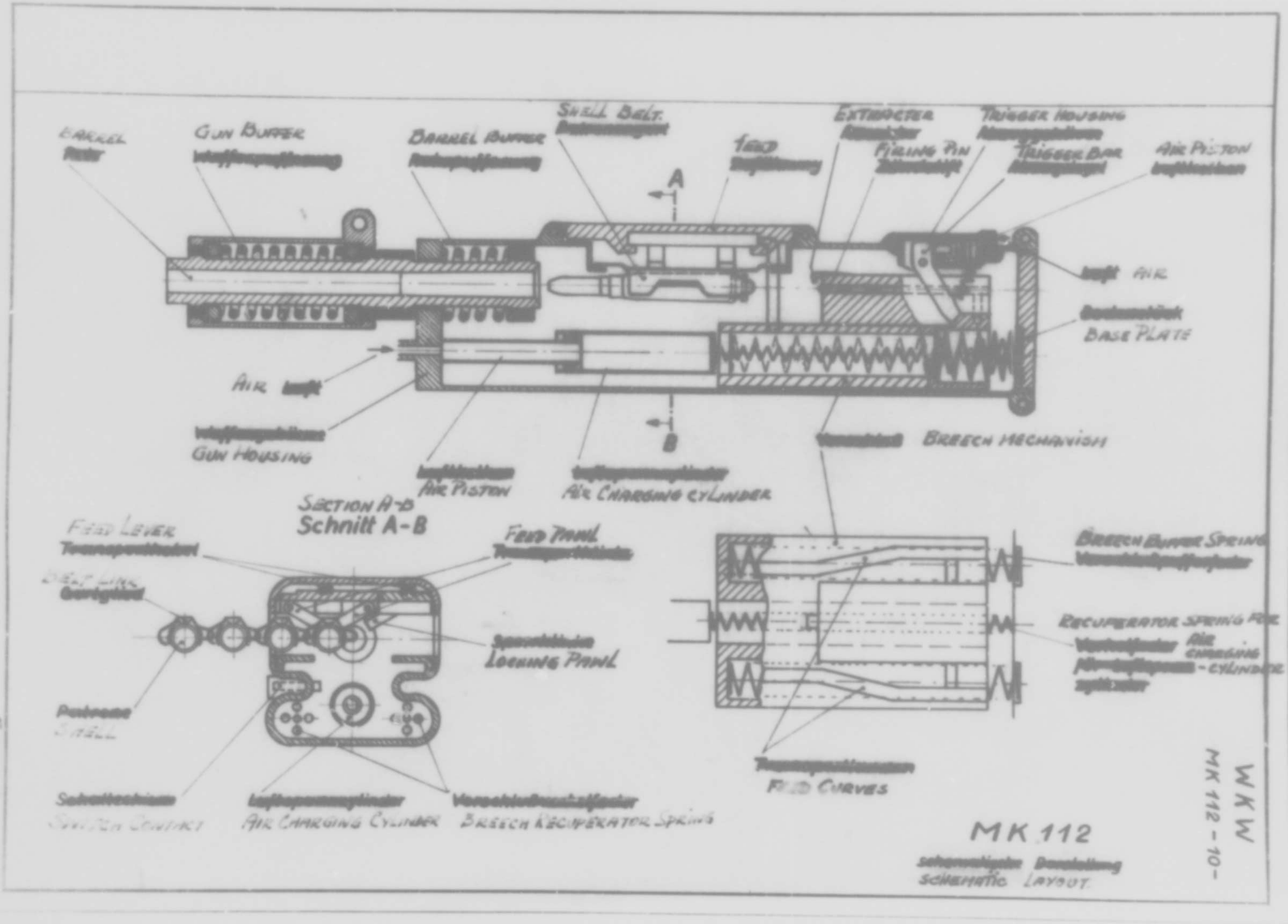
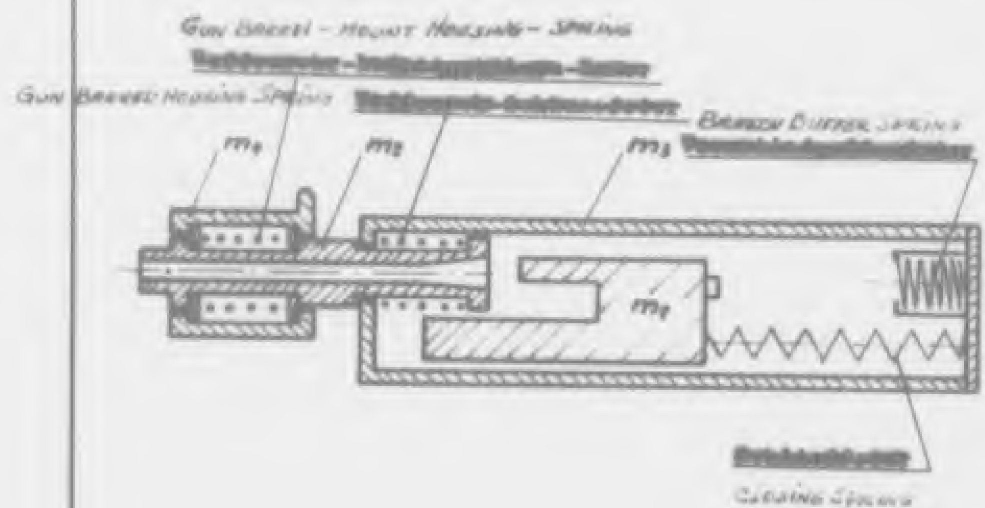

BARREL
GUN BUFFER
BARREL BUFFER
SHELL BELT.
FEED
EXTRACTER
FIRING PIN
TRIGGER HOUSING
TRIGGER BAR
AIR PISTON
AIR
BASE PLATE
A
B
AIR
GUN HOUSING
AIR PISTON
AIR CHARGING CYLINDER
BREECH MECHANISM
SECTION A-B
Schnitt A-B
FEED LEVER
BELT LINK
FEED PAWL
LOCKING PAWL
SHELL
SWITCH CONTACT
AIR CHARGING CYLINDER
BREECH RECUPERATOR SPRING
BREECH BUFFER SPRING
RECUPERATOR SPRING FOR AIR CHARGING CYLINDER
FEED CURVES
MK 112
SCHEMATIC LAYOUT.
WKW
MK 112 -10-

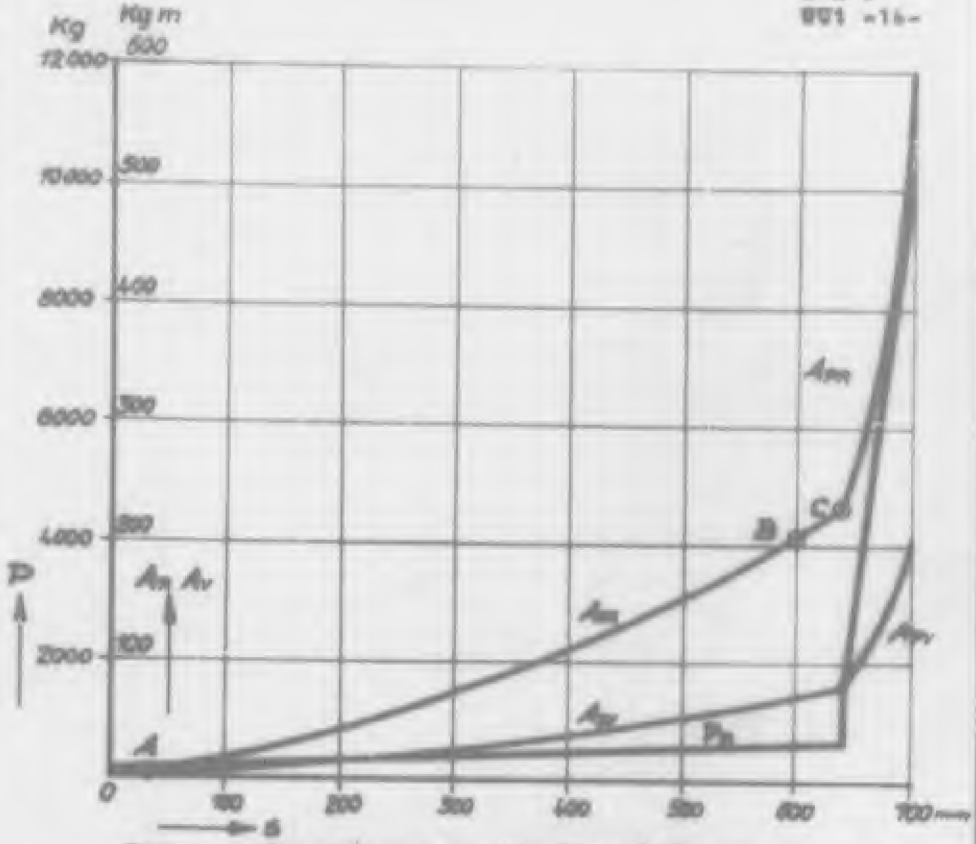
FIGURE 1.



[redacted]: [redacted]

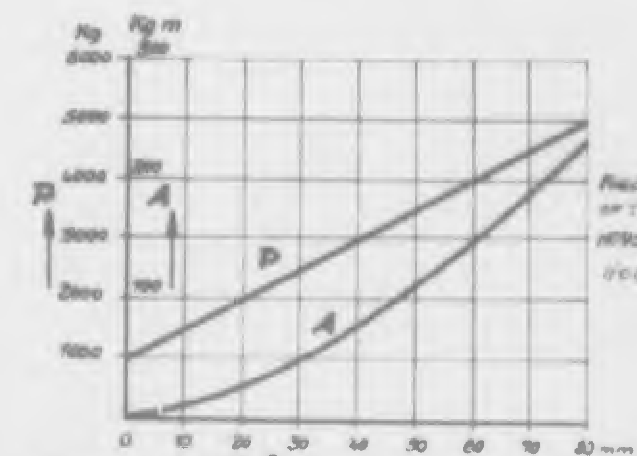
[redacted] Gun Fuse MK-112

Fig. 2



[redacted]
Figure 3

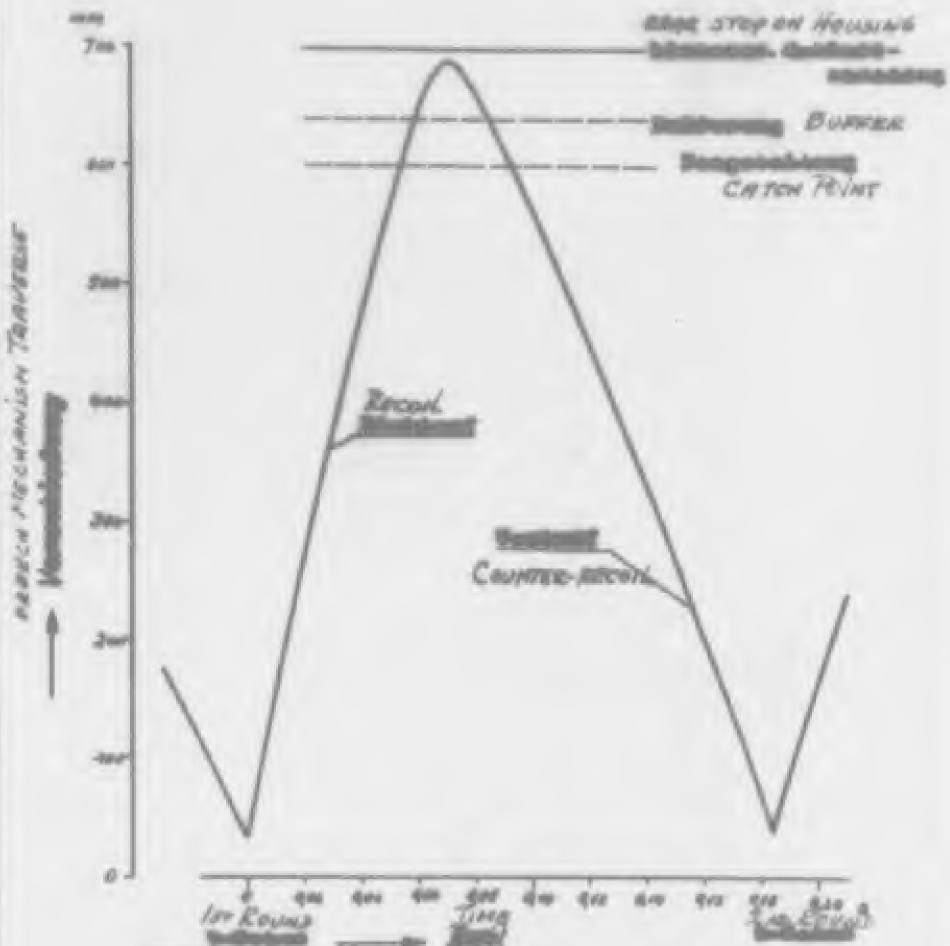
Spring Strength and Work Potential of the [redacted]
Closing Spring and Breech Buffer Spring



Forces and energy absorption of the [illegible] housing spring and the [illegible] housing spring.

Figure 4

[redacted]

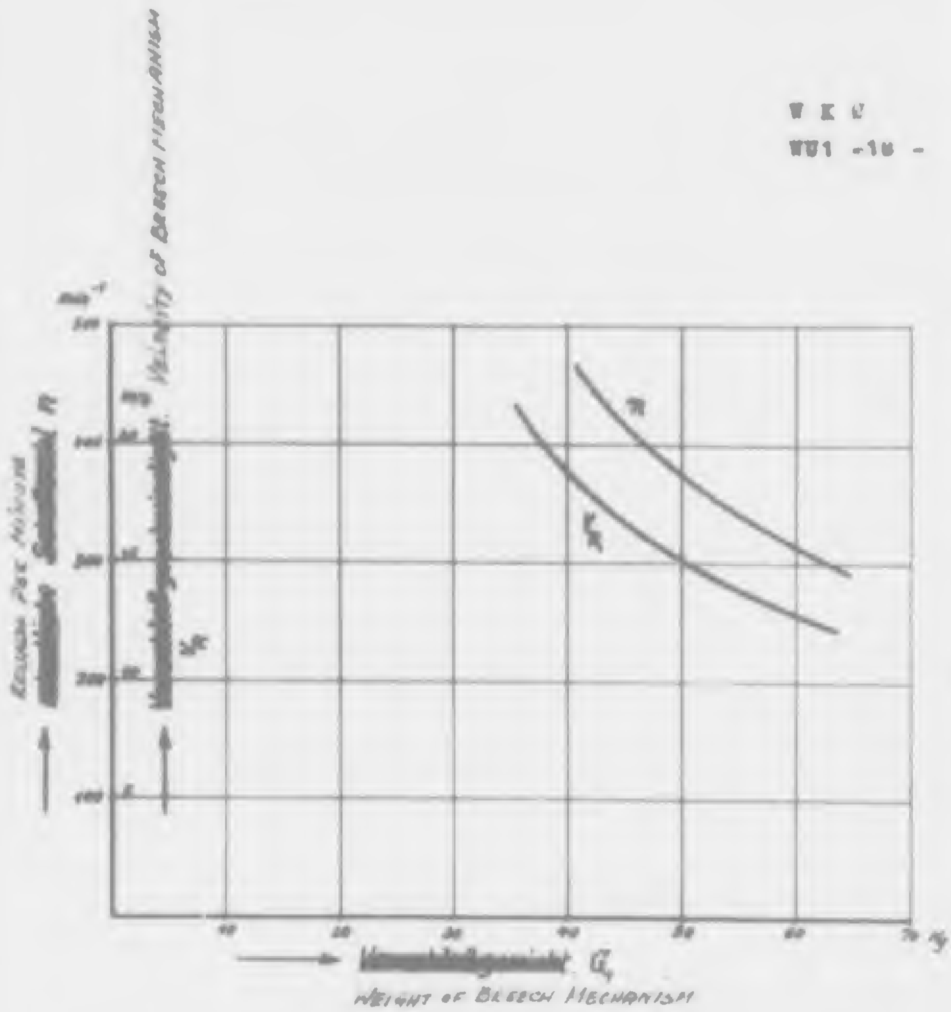


CALCULATED DISTANCE-TIME DIAGRAM FOR MG 11

n = 324

ROUNDS PER MINUTE

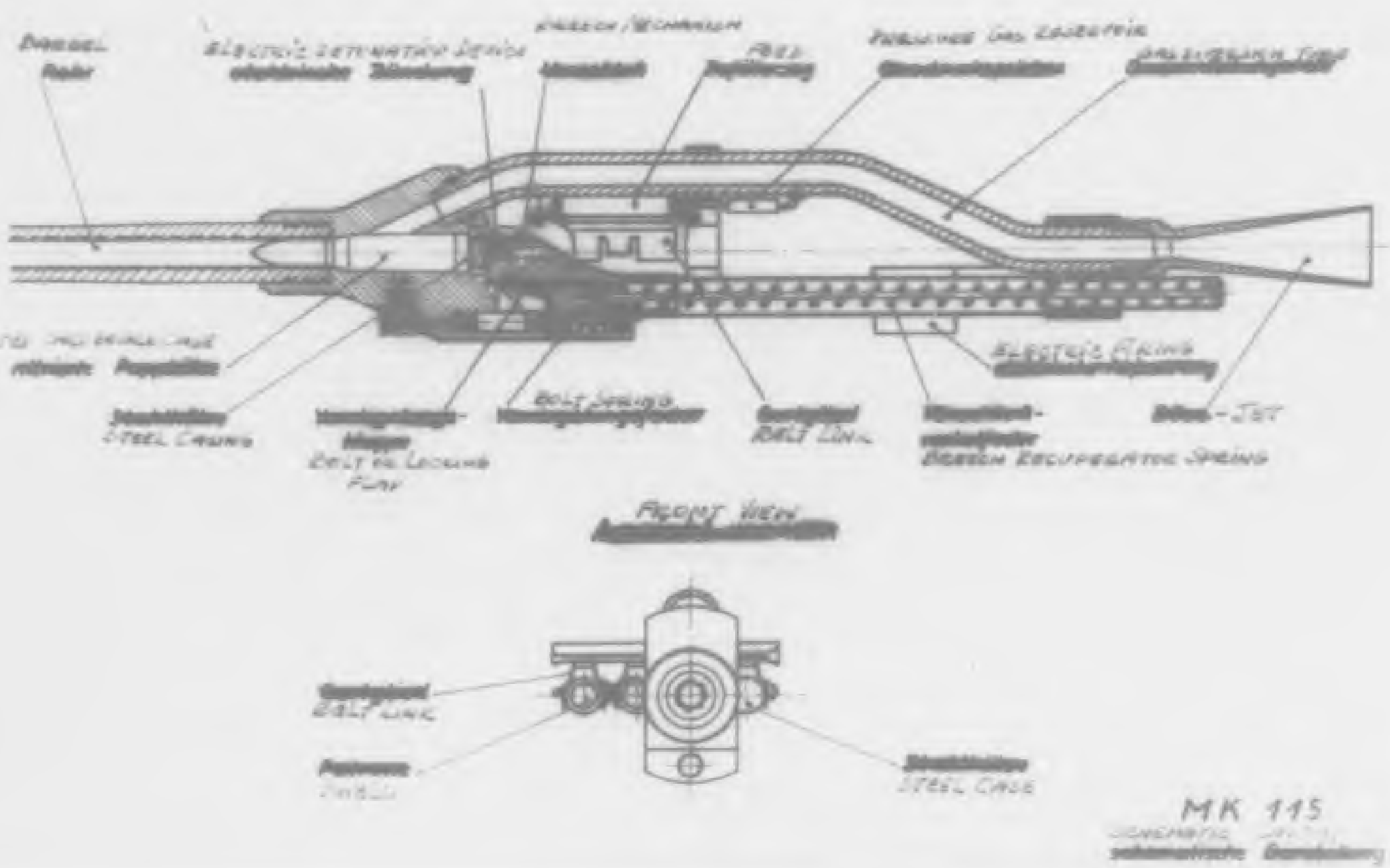
W K W
WU1 -16 -



[illegible]

CYCLE RATE n AND BREECH VELOCITY v_R DEPENDENT ON WEIGHT OF BREECH MECHANISM

Fig. 6


BARREL
ELECTRIC DETONATING DEVICE
FEED
ELECTRIC FIRING
STEEL CASING
BOLT SPRING
BOLT LINK
BREECH RECUPERATOR SPRING
FRONT VIEW
BOLT LINK
STEEL CASE
MK 115

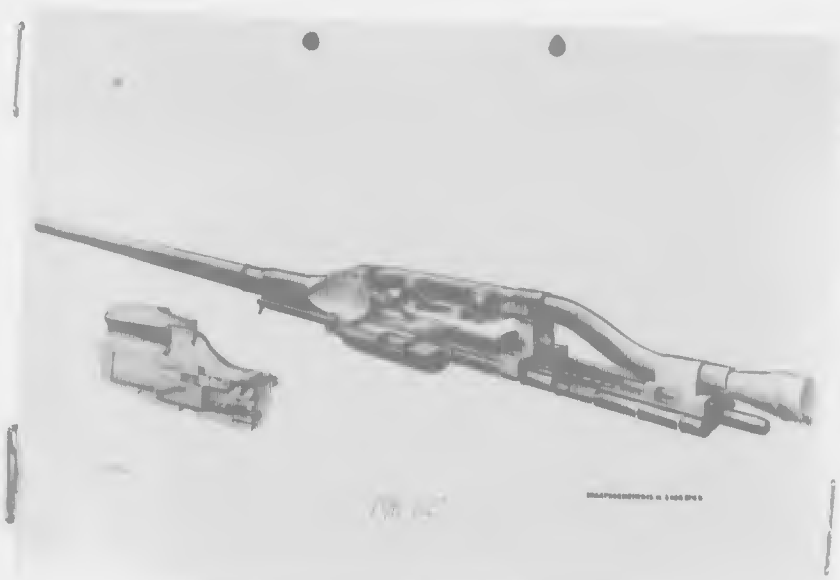


Figure 8

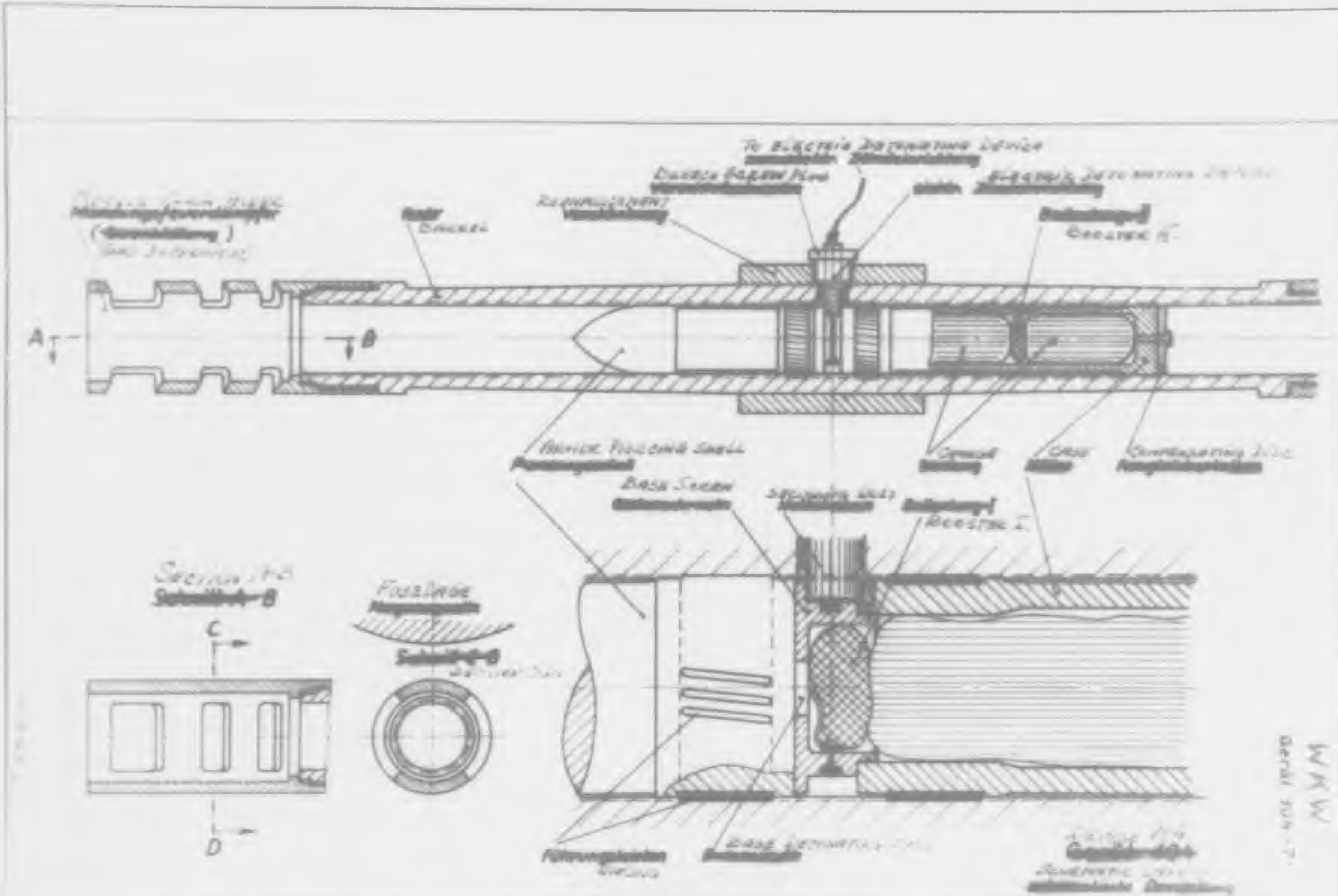
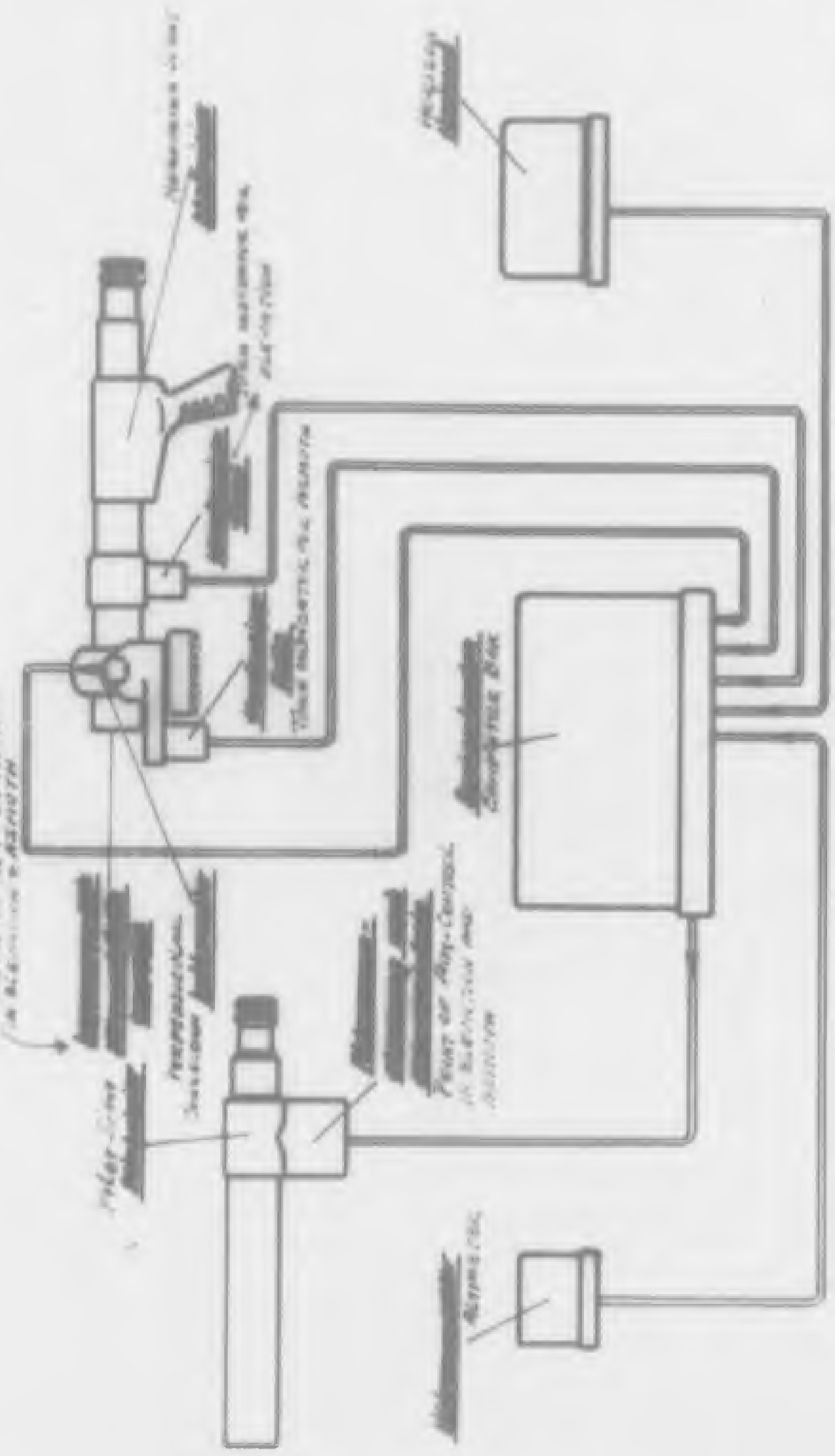

To Electric Detonating Device
Electric Detonating Device
Booster II
Armor Piercing Shell
Base Screw
Booster I
Case
Section A-B
A
B
C
D
WKW
Gerät 104-7

Figure 10

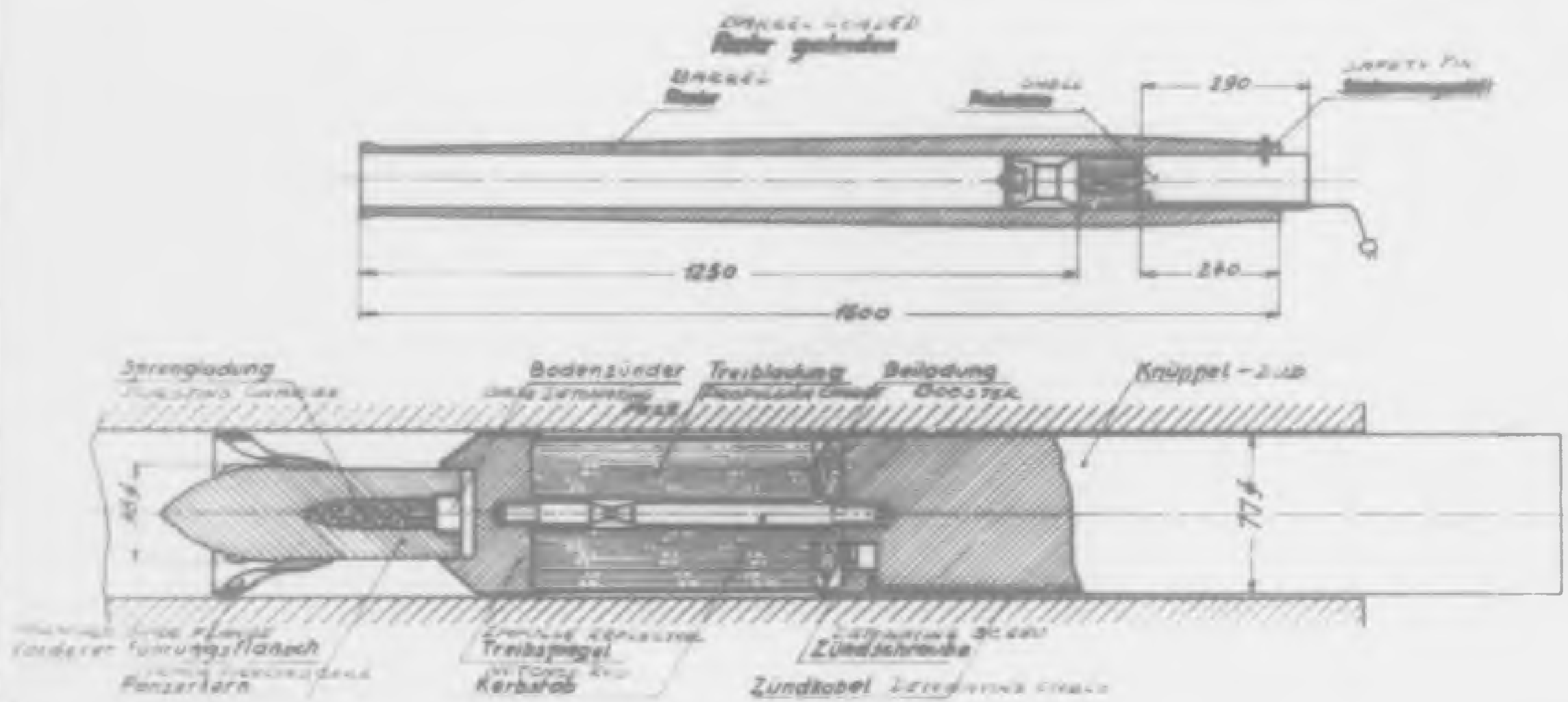
Figure 11

WKW
Gerät 104-10



SKETCH SHOWING OPERATING PRINCIPLES OF THE SIGHT 104

Fig. 12



SG 113 A
Schematische Darstellung

W.K.W.
SG 113 A-5

Fig. 13

Figure 14

Figure 15

Figure 16

Figure 17

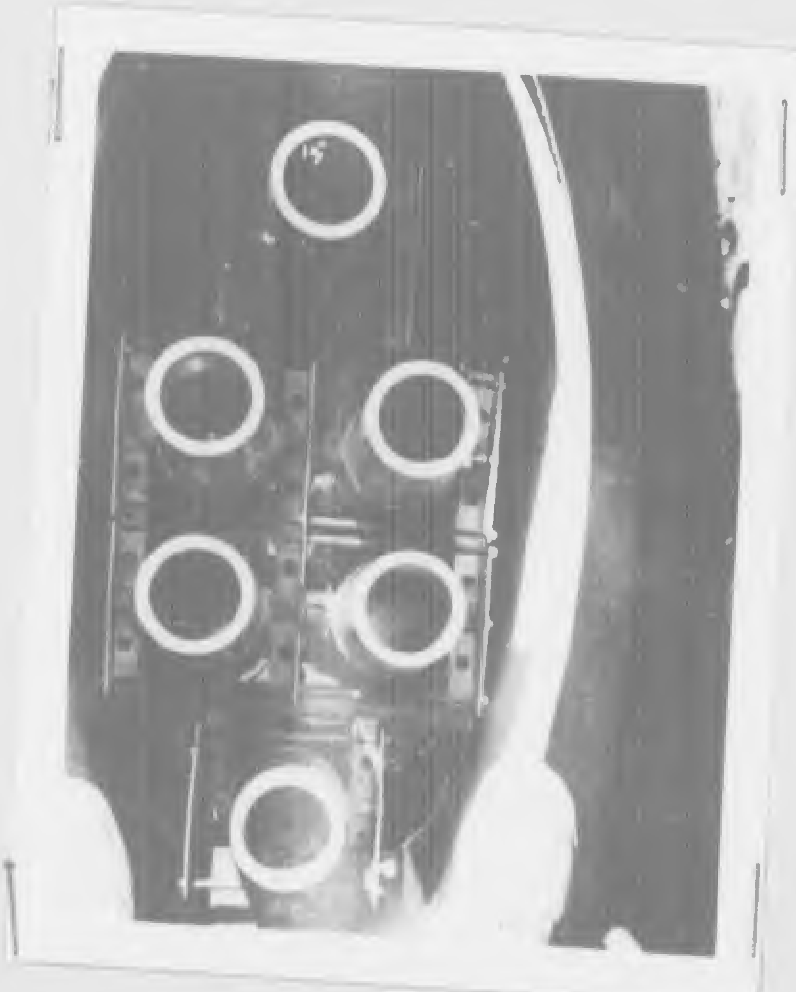
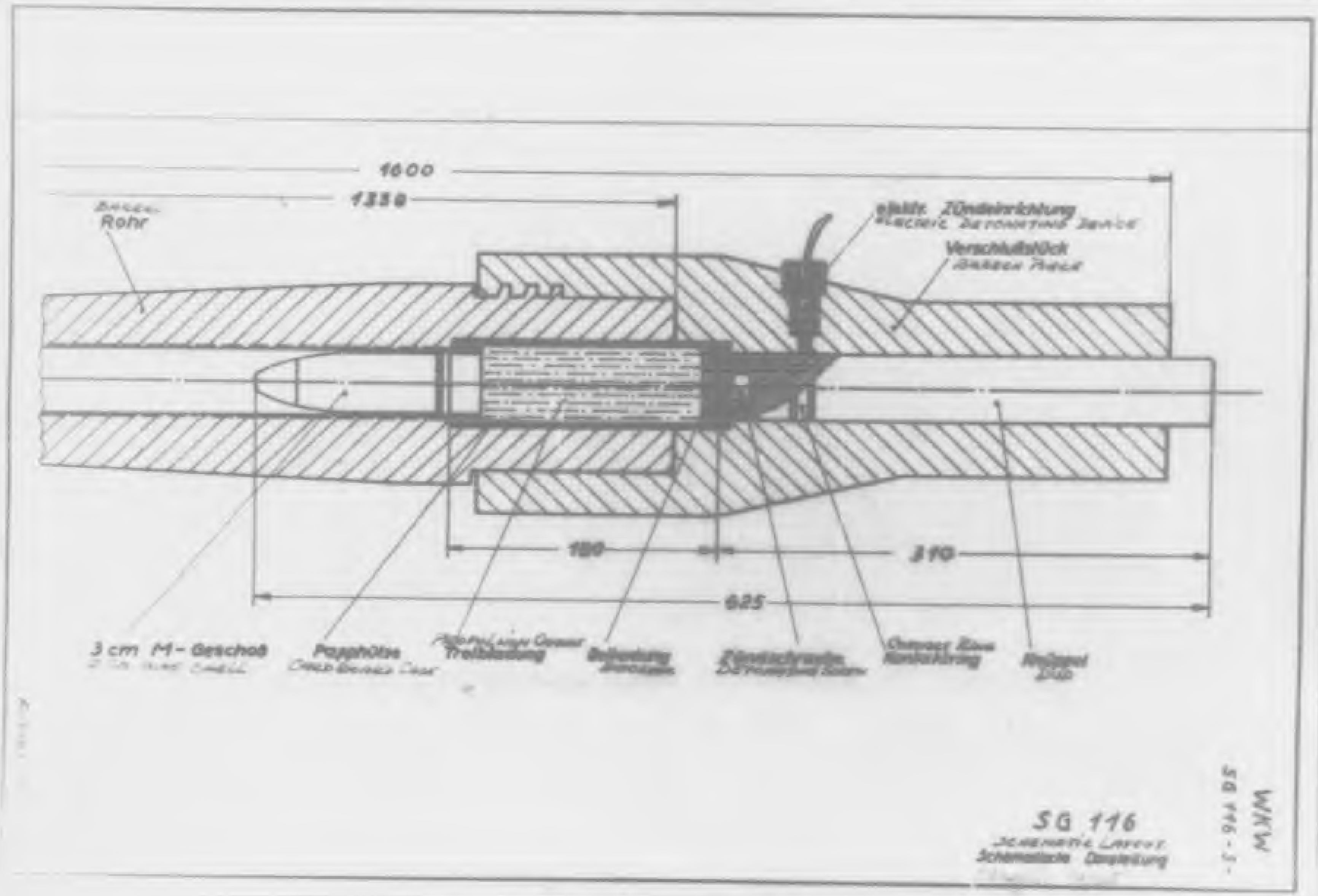
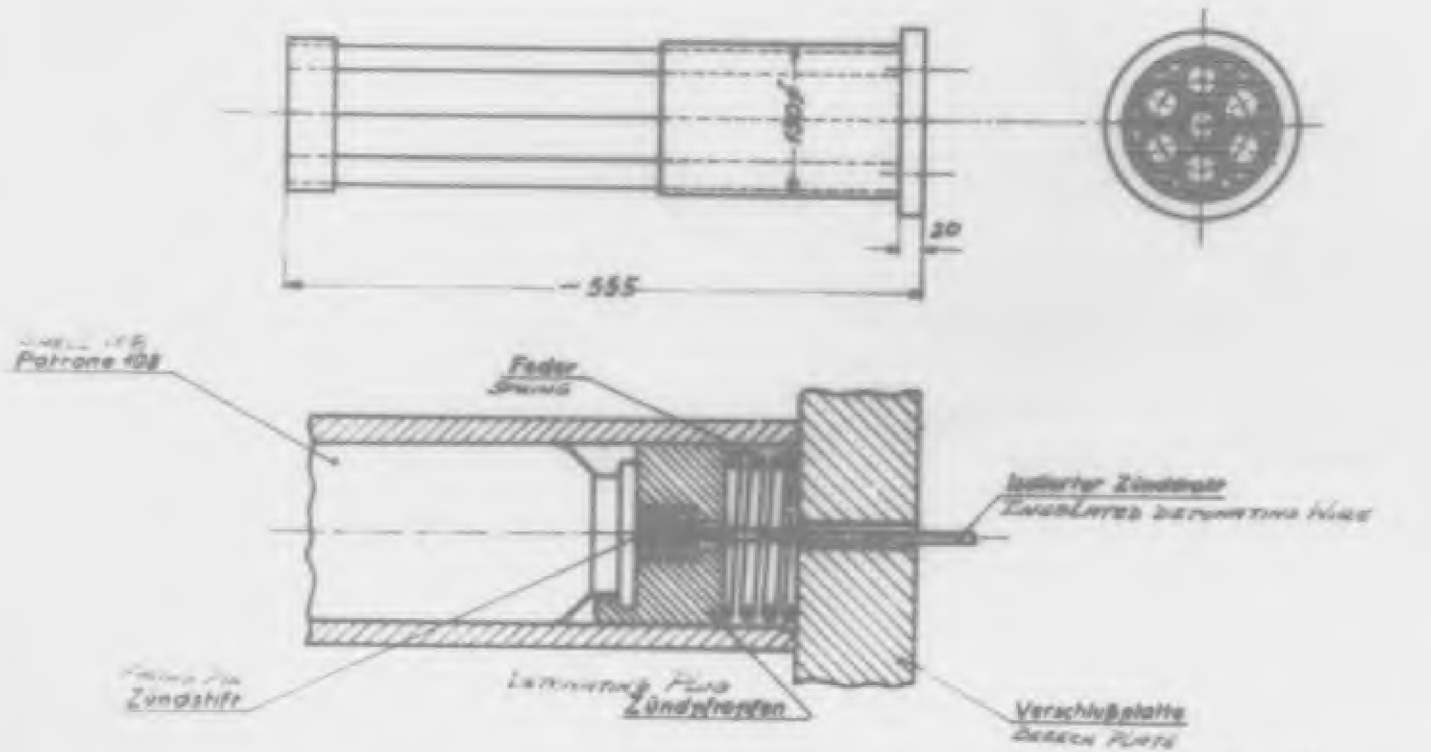


Figure 18



1600
1350
Barrel
Rohr
elektr. Zündeinrichtung
Electric detonating device
Verschlußstück
Breech piece
180
310
625
3 cm M-Geschoß
3 cm mine shell
Papphülse
Cardboard case
Treibladung
Zündschraube
Kontaktring
Prallgas
SG 116
Schematic layout
Schematische Darstellung
WKW
SG 116 - 3 -

WKW
SG-4-



SG 117
schematische Darstellung

Fig. 20

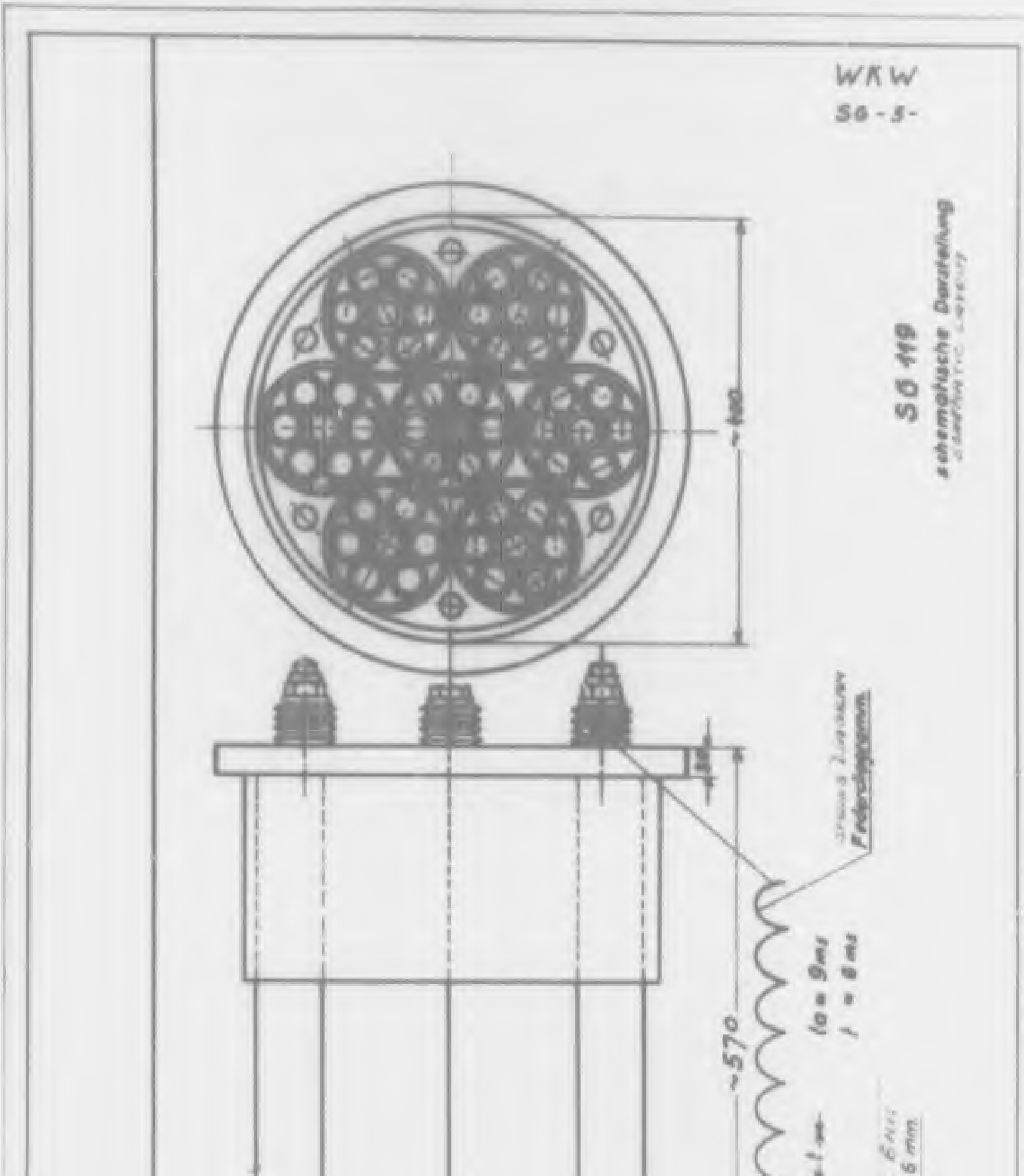
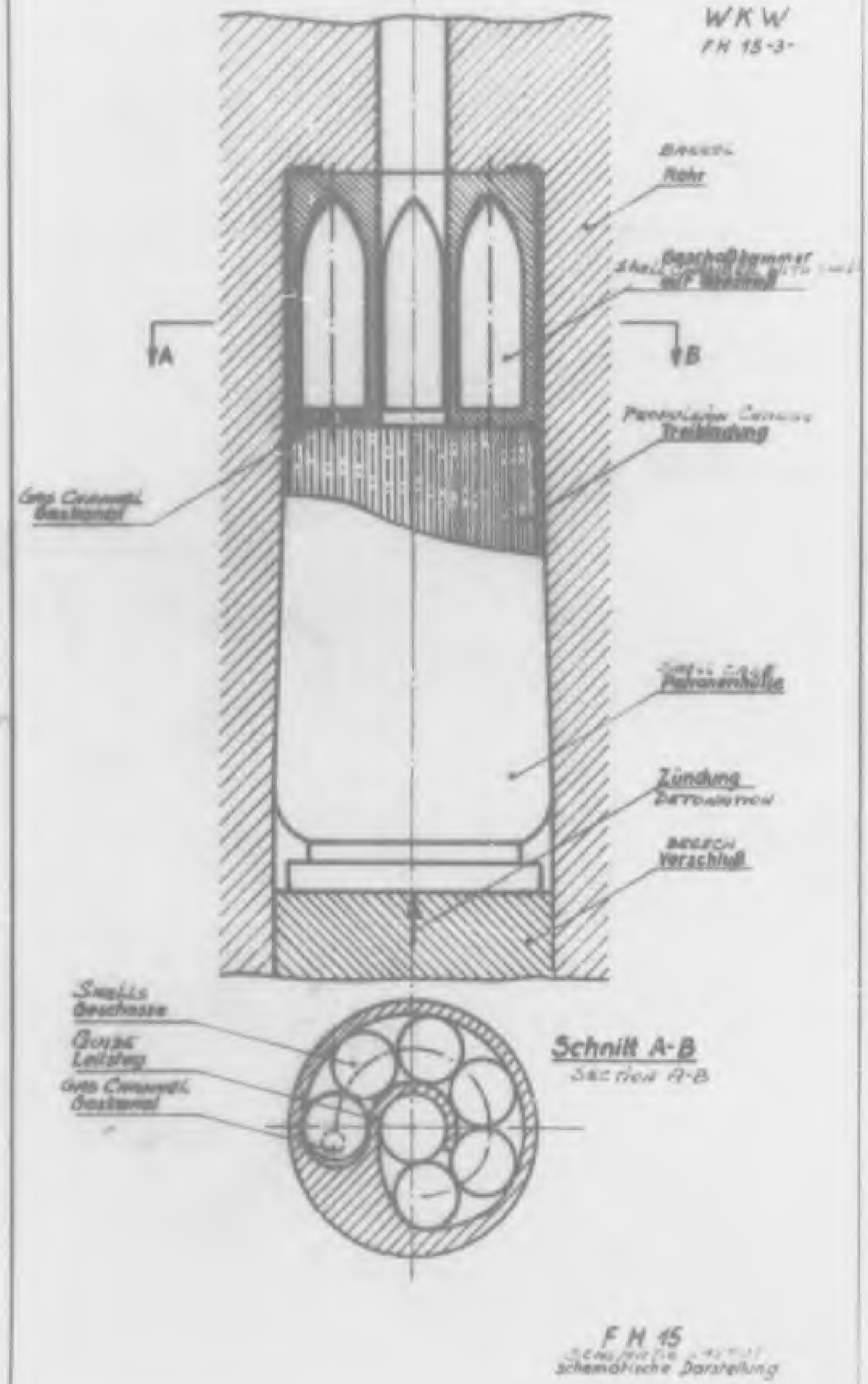

WKW
SG-5-
SG 119
schematische Darstellung
~100
~570
Federdiagramm
lo = 9ms
l = 6ms
Rücklauf max 6 mm

Fig. 21



WKW
FH 15 -3-
BARREL
Rohr
Geschoßkammer
mit Geschoß
PROPELLING CHARGE
Treibladung
Gas Channel
Gaskanal
A
B
SHELL CASE
Patronenhülse
Zündung
DETONATION
BREECH
Verschluß
Shells
Geschosse
Guide
Leitsteg
Gas Channel
Gaskanal
Schnitt A-B
Section A-B
F H 15
schematische Darstellung

Figure 23

3. The MK 114 Gun (5.5 cm.)

The Ordnance Bureau of the Air Ministry set up the following requirements for the development of this automatic cannon: caliber 5.5 cm; muzzle velocity 1000 m/s; shell weight 2.0 kg.; explosive at least 0.4 kg.; cyclic rate at least 150 rounds; to be not over 1000 kg.; no alloy steels to be used; simple construction; electric firing; remote control; for use either as fuselage or engine mounted gun.

The gas pressure loading system with fixed bolts was to be used. The design of the gun was quite difficult. The specified total weight of not over 1000 Kg. allowed a gun weight of about 700 kg. The use of non-alloyed steels seriously compromised the design. The various models that were completed came close to the requirements in their general structure but never met the main requirements fully. The ammunition for the 5.5 cm. Flak Device 58 was to be used. In order to keep the recoil force down, a recoil mechanism with a brake was provided. Further developmental work on this device was stopped in the fall of 1944 by order of the Air Ministry. The following table gives the ballistic and technical data concerning this gun:

Caliber......................	cm	5.5
Muzzle velocity..............	m/s	1050
Weight of projectile.......	kg	1.8
Weight of explosive........	kg	0.49
Weight of case loading.....	kg	1.1
Muzzle energy...............	mt	110
Weight of round............	kg	4.8
Type of detonation.........		electric
Length of barrel............	mm	4210
Weight of barrel............	kg ca.	250
Maximum gas pressure.......	kg/cm^2	2900
Gun system...................		gas pressure with fixed bolt.
Rate of fire.................	spm.Sch/min.	150
Weight of gun...............	kg	700
Type of feed................		link belt, right or left.
System for firing...........		electro-pneumatic
Impulse......................	mt	250

4. The MK 115 (5.5 cm.) Automatic Jet Cannon.

(a) Evolution

The Ordnance Bureau of the Air Ministry, Berlin, set up the following requirements for an automatic recoil-less jet cannon for aircraft. Caliber 5.5 cm; muzzle velocity 600 m/s; shell weight 0.4 kg.; rate of fire at least 300 rounds per min.; freedom from recoil; no alloyed steels to be used; simplest construction; electric firing; remote control; belt feed from right or left; empty cases to be pulled back into the belt; possible use as wing gun.

The gun system, namely a recoil-less jet cannon, required a special arrangement for the bolt action and the feed. The usual metal shell case could not be used because of the gas diversion tube. It was replaced by a combustible type of case made of nitrated cardboard with a metallic base piece. Because the gas diversion tube was on one side, the bolt mechanism was put on the other. Because there was no suitable moving part to operate it, and since a belt lift of 2 meters was required, the drive for the belt feed was activated by gasses drawn from the gas diversion tube.

The first completed model was intended to serve as a model for basic study and production design was not given much attention. The model was never quite finished, hence final tests were never made.

(b) Description. (See Figures 7 and 8)

The gun consists of (a), the barrel; (b), breech block; (c), bolt including electric detonator; (d), bolt recuperator device; (e), feed: (f), electro-pneumatic charging device; (g), electro-pneumatic trigger; (h), gas diversion tube with jet and bolt buffer; (i), electric contact; and (k), cartridge belt.

The monobloc barrel is screwed into the front part of the breech block.

The breech block serves to hold the bolt action, the gas diversion tube and the gas pick-up and piston for opening the bolt. The main

4. The MK 115 (5.5 cm.) Automatic Jet Cannon. (b) (Cont'd.)

boring is formed into a shell chamber, and onto the front end of it the rifled barrel is attached directly. There is a shoulder on the back side of the breech block which gives upward support to the bolt which is only locked on its lower side. On the right side are the lugs for attaching the electric contact block. The gas diversion tube is inserted and fastened in the upper boring, which runs backward at an angle of 25°.

The bolt is made of one piece. The locking surface is on one side and the recess for the bolt recuperator spring is on the back. The electric firing pin is built into the central boring. An oblique boring, from the firing pin, passes down to the right for the firing current leads from the switch contact. The ejector with its spring are on the top.

The bolt recuperator device consists of an overlaid spiral compression ring with a spring-guide tube. This tube is fastened in the bolt in front and to the under side of the jet at the back. The recuperator spring is precompressed when installed.

The feed housing is a partly welded, stamped sheet metal assembly and is fastened to the gas diversion tube and to the U-shaped bolt guide rails that run along the sides. The feed can be changed over for either right hand or left hand feed. The feed is driven by means of a gas storage chamber, that is supplied through a boring into the side of the gas diversion tube. The belt entry opening is clam-shaped to facilitate feeding.

The charging device is on the left bolt guide rail. The air piston is constructed as a telescoping piston and is moved forward again by compressed air at the end of the charging procedure.

The electro-pneumatic trigger is located in the back part of the gun and is fastened to the right bolt guide rail. The trigger bar is actuated by an air piston.

The gas diversion tube is fastened in the breech block and is so shaped that at the back part of the gun it runs in line with the axis of the barrel again and is connected to the two bolt guide rails by a cross yoke. The gas jet is threaded onto the gas diversion tube and held with

4. The MK 115 (5.5 cm.) Automatic Jet Cannon. (b) (Cont'd.)

a set-screw. The two bolt buffers, right and left, are built into the cross yoke between the two bolt guide rails beside the closing spring.

The electric switch contact is joined to the right side of the breech block and fastened behind to the right bolt guide rail. It is made of stamped sheet metal construction and contains the firing stud for the contact of the electric firing device. A lever in the back of the switch contact controls the shell feed by means of a contact.

The cartridge belt is made of carbon steel stampings. It is equipped with hooks and eyes which cause the belt to disintegrate if a shell is missing. After the belt receives the short base section of the case, it disintegrates. At front and back are the rails necessary for the feeding of the belt, and to the right and left rear are the two hooks for the ammunition feed channel. The belt has the necessary flexibility for any manner of feed that might be encountered.

(c) Operation.

The gun system is constructed as a fixed breech action with jet effect, in order to achieve a recoil-less mounting.

When the electro-pneumatic trigger is actuate, the bolt moves forward under the pressure of the bolt recuperator spring and shoves a shell from the belt into the loading chamber. The breech flap, built into the breech block, swings upward and locks the bolt. Just as the breech flap moves into its extreme position, it closes the contact for the firing current and the shell is fired.

The shell casing, of nitrated cardboard, burns and the resulting gases pass upward through the gas diversion tube and out to the rear through the jet. At the same time, gases flow through the gas canal in the back of the breech block and actuate the gas piston, which must move a certain distance in order to force the breech flap down out of the bolt. The movement of the gas piston is so determined that complete unlocking of the bolt does not occur until the jet effect ends and the gas pressure in the barrel is still high enough to snap the bolt back against its recuperator springs. The bolt is snapped back by the gas pressure on the bottom of the metal base of the cartridge. As the bolt moves

4. The MK 115.(5.5 cm.) Automatic Jet Cannon. (c).(Cont'd.)

back, the ejector pulls the empty case into the belt link and ejects it. Just before the bolt reaches its back position, it strikes the bolt buffers to the right and left and thus has its recoil limited. The bolt recuperator spring and bolt buffers then throw the bolt forward again.

During the passage of the gases through the gas diversion tube, some gas is stored up in the gas reservoir, and this reservoir is closed off by a one way valve. The bolt, in moving backward, opens the gas reservoir electro-pneumatically so that the gases stored there can actuate the feed. The belt is thus moved and a new shell is pushed into the center line of the gun.

The air charging device built on the left side, can only pull the bolt back out of its locked position if the breech flap is moved by hand. Hence misfires cannot be cleared by the air charging device. For this reason, an electric auxiliary detonator is attached to the left side of the breech block, which is intended to ignite the misfire from outside by setting off the nitrated cardboard case. Stoppages caused by cases striking or shells become telescoped can be cleared with the air charging device.

(d) Assessment.

Only one model gun was completed. Operational tests were to be made with this gun but due to war events, the gun was never fired.

Experiments to determine the jet effect and freedom from recoil were made with actual barrels but without automatic mechanism. Altogether about 500 rounds were fired. Complete freedom from recoil was achieved with this test gun.

Numerous ammunition problems were encountered. The manner of fastening the projectile to the cardboard case, and the manner of attaching the case to the metallic base were never firmly established. Attempts to increase rate of feed resulted in loosening the projectile and telescoping it into the case.

Hot and cold tests and tests at different altitudes were not made.

4. The MK 115 (5.5 cm.) Automatic Jet Cannon. (d) (Cont'd.)

These were to be made with the first automatic model. Slow motion movies were made of the jet effect and the movement of the gun in firing. Experiments to determine the effect of the jet on aircraft parts were not completed. The following table gives the ballistic and technical data concerning this gun:

General Data.

Caliber	cm	5.5
Muzzle velocity	m/s	600
Weight of projectile	kg.	1.48
Rate of fire	/min	300
Weight of gun	kg.	190
Length of gun	mm	5500

Ammunition.

Weight of projectile	kg	1.48
Length of projectile	mm	220
Weight of explosive	kg	0.420
Weight of propellant	kg	0.500
Weight of case	kg	1.0
Weight of round	kg	3.0
Length of round	mm	480
Detonation	electric	

Barrel.

Caliber	cm	5.5
Length	mm	1200
Weight	kg	45
Length of rifled part	mm	1200
Number of grooves		20
Diameter through grooves	mm	56.5
Width of lands	mm	4.5
Type of twist	constant	
Twist at start		8°30'
Twist at end		8°30'
Maximum gas pressure	kg/cm^2	2800
Design pressure	kg/cm^2	3200

4. The MK 115 (5.5 cm.) Automatic Jet Cannon. (d) (Cont'd.)

Gun.

Gun system - low recoil jet with fixed breech.

Weight	kg	190
Length	mm	3300
Type of feed	belt	
Weight of link	kg	0.350
Weight of belt with 100 rounds	kg	335
Length of bolt recoil	mm	660
Weight of belt	kg	10
Recoil	none	
Weight of recoiling parts	kg	10
Type of brake	none	
Type of recuperator	none	
Type of charging	electro-pneumatic	
Type of firing	electro-pneumatic	
Type of detonation	electric	

5. Device 104 (35 cm.)

(a) Evolution.

With the approval, and at the request of the Air Ministry in 1939, Rheinmetall-Borsig developed a type of gun barrel that would permit firing a shell weighing 700 kg. from an aircraft. Special airplanes with this gun installed, were to make dive attacks on battleships. It was required that the entire deck armor plate be penetrated even at an angle of impact of 60°. An impact velocity of about 450 m/s was necessitated by this requirement. Of this, 125 m/s might be assumed to come from the dive velocity of the airplane and 325 m/s from the initial velocity of the shell.

Freedom from recoil was achieved by making the shell case the same weight as the shell itself and by firing it out of the rear of the gun simultaneously as the projectile left the gun. Any torque strains on the mount were avoided by rifling right hand twist the entire barrel.

5. Device 104 (35 cm.) (a) (Cont'd.)

The effect of the muzzle gas pressure on the airplanes fuselage was reduced by means of a suitably designed muzzle brake.

(b) Description. (See Figures 9, 10 and 11)

The Device 104 was to be mounted in an airplane so that it could be lowered hydraulically into position beneath the fuselage. The gun itself consists of the following: (a) barrel with muzzle brake and reinforcing parts, (b) the shell, (c) the shell case with the charge, (d) the electrical firing device.

The barrel is provided with a constant right hand twist throughout its entire length. In the middle there is a hole for the electrical firing device. This weakening of the cross section was compensated for by a reinforcement ring fitted tightly around the middle of the barrel. The muzzle brakes are screwed on both ends of the barrel. They serve to disperse the muzzle gas pressure wave so as to minimize damage to the aircraft.

The shell is an armor piercing shell with base detonating fuze. At its after end are grooves into which the ribbed guides of soft iron are pressed. The ribs run in the grooves of the rifling. The after end of the base screw also has an insulated inset contact ring around its circumference and through this, the firing current is transmitted to the detonating screw which is set in the middle of the base screw.

The shell casing contains the charge that is fired by two ignition charges. The same type of ribbed guides used on the projectile itself are also pressed into grooves on the forward end of the case. By screwing compensating plates on or off the after end of the case, it is possible to equalize weight differences which occur in manufacture. The shell and the case are put together into a unit and held by three shear pieces set into recesses in the case and into a groove in the base screw of the shell. To prevent them from falling out, the shear pieces are held by screws. The entire shell unit is held in the gun barrel by the electric firing arrangement.

The electric firing arrangement consists of two main parts: a bolt or breech screw and a holding bolt. The breech screw which absorbs the

5. Device 104 (35 cm.) (b) (Cont'd.)

gas pressure, is screwed into the reinforcing ring. The holding bolt presses against the latter. The spring contact pin is in the holding bolt and conducts the firing current to the contact ring on the base screw and thence to the detonating screw. The holding bolt is milled off on both sides at its lower end and these two flat surfaces fit into the groove remaining between the shell and the case and thus hold the entire shell unit in the barrel.

(c) Operation.

The firing current passes through the spring contact wire of the electric firing device into the contact ring on the base screw and from it to the detonating screw. The igniting or detonating spark from this goes to the first and then to the second booster or igniting charge, the second one dividing the main charge into two halves, and then the main charge in the case is detonated. The gas pressure drives the shell out the front and the case out the back of the barrel. Because the trailing edge of the shell and the trailing edge of the case both leave the muzzles at practically the same time, practically no recoil impulse is transmitted to the barrel or to its mount. The muzzle gas pressure is vented through the lateral openings in the muzzle brake, which are uncovered in succession by the shell and casing as they pass through the barrel. In this way, the gas pressure wave that comes out the main openings in the barrel is greatly reduced.

(d) Assessment.

Tests proved the freedom from recoil of the device. For these tests, the device was mounted on a car as shown by Figures 10 and 11. Forward and backward movements of only about 10 mm. were measured.

By mounting an airplane fuselage over the device as to correspond with actual installations, it was found that damage to the outer skin of the fuselage near the muzzle brakes was slightly excessive. By reinforcing the fuselage at the points concerned, these difficulties were eliminated without any change in the design of the device itself.

The experiments showed that a special airplane would definitely have to be developed to carry such a barrel, and that the requirements,

5. Device 104 (35 cm.) (d) (Cont'd.)

especially as far as muzzle gases were concerned, would have to be given very careful consideration. About 15 test shots were fired with the test barrel.

The development of this device was stopped in September 1939 because higher priority projects were assigned.

(e) Ballistics and Sight.

The Device 104 was intended to make possible an aimed single shot against a battleship or carrier from outside the effective defensive range of such surface vessels. This was taken, to mean that the release of the projectile must occur at altitudes not less than 3000 to 4000 meters. The initial velocity of 325 m/s provides certain penetration of the deck armor plate as well as a good probability of getting a hit because of the short flight time. Assuming a dive velocity of 125 m/s, there results a time of flight for the shell of about 9 sec. from 4000 meters, or about 1/3 of the drop time required by a bomb released in horizontal flight. The shell, fired from an airplane while diving, loses very little velocity (only about 10-20 meters per second from 4000 meters) so that an impact velocity of over 400 m/s is achieved. This can otherwise be reached only with propelled bombs. Comparative calculations showed that this penetrating power was ample to penetrate deck armor 220 mm. thick at an impact angle of 60°. The successful use of Device 104 depends on how far it is possible to combine the short flight time and the small angle of elevation and lead angle into a technically successful sight.

The sighting method that was proposed for actual use, computes the lead angle from the rate of change of angle of the attacking airplane. The range was figured from the altitude and the dive angle. The lead was computed as the product of the angular velocity times the time of flight of the shell. A measuring sight was devised to give the rate of change of angle. This device was controlled and pointed by a special gunner. The rates of change of angle were measured by a turn indicator, controlled by the sight used by the special gunner. The values were fed into a computer in which the range values, given by an altimeter and a horizon, were converted into firing leads. These values were then transmitted to a pilot sight. In order to increase the accuracy of

5. Device 104 (35 cm.) (e) (Cont'd.)

point of aim as much as possible, a six power magnification was planned for the pilot sight (Figure 12).

Tactically the sight was to be used as follows: at about 5000 m. the airplane would go into a dive of about 60-80°. After 5 seconds, the lead was being fed to the pilot sight, so that the gun might be fired from 4000 m. Tests and experiments were made with the angle speed sight, since it was considered important to see whether or not the rate of change of angle which is relatively small could be eliminated from normal flight irregularities. It was found that the use of special damping systems made this quite feasible. The following table gives the ballistic and technical data concerning Device 104:

General Data.

Caliber	mm.	350
Muzzle velocity	m/s	325
Weight of projectile	kg.	700
Weight of case	kg.	700
Weight of complete weapon, loaded	kg.	5000
Length of gun with muzzle brakes	mm.	10000
Number of shots	1	

Round of Ammunition.

Weight of projectile (A.P.)	kg.	700
Length of projectile	mm.	1200
Weight of explosive	kg.	35
Weight of propellant	kg.	70
Weight of boosters	kg.	2 x 0.200
Weight of case	kg.	700
Weight, complete round	kg.	1470
Length of round	mm.	3000
Type of detonation	electric	
Muzzle velocity	m/s	325

5. Device 104 (35 cm.) (e) (Cont'd.)

Barrel.

Caliber	mm.	350
Length	mm.	7000
Length of rifled part	mm.	7000
Weight of barrel with muzzle brakes	kg.	3500
Number of grooves		30
Diameter, through grooves	mm.	371
Width of lands	mm.	20
Type of twist	contant -	right hand
Maximum gas pressure	kg/mm2	1800
Design gas pressure	kg/mm2	2200

6. SG 113A (7.7 cm. - 4.5 cm.)

(a) Evolution.

The Ordnance Bureau of the Air Ministry and the Air Research Center at Braunschweig, together, developed a system for attacking armored vehicles and tanks from aircraft flying at altitudes of 5 to 10 meters. An automatic firing system (based on magnetic principles) was developed for this purpose. A single shot weapon of sufficient caliber to destroy a tank with one shot was to be used. This large caliber single-shot gun was to be of the non-recoil variety similar to the Device 104, described in Paragraph 5 above. It was to be made recoil-less by firing two masses of equal weight out of both ends of one barrel.

This was first worked out with the 7.5 cm. hollow charge armor piercing shell of 3 kg. shell weight, which was fired from the middle of a barrel 1600 mm. long, together with a counterweight of the same weight. Further developments proved that this shell was unsatisfactory. Hence it was decided to try to get the desired results with a sub-caliber armor piercing shell, which would pierce the armor and then explode inside.

With this in mind, Rheinmetall-Borisg (who had been asked to participate in the project) developed an armor piercing core 5 cm. thick, inside an aluminum casing. The total shell weight was only about 1.5 kg.

6. SG 113A (7.7 cm. - 4.5 cm.) (a) (Cont'd.)

Since this shell needed higher muzzle velocity to penetrate the required 40 mm. thickness of armor plate, the weight of the dud was increased and the assembly was fired, not from the middle of the barrel but from a point where the length of shell travel and length of dud travel are in inverse ratio to their weights.

With this arrangement, a muzzle velocity of about 700 m/s was attained. To make manufacturing of the barrels simpler, a smooth bore was to be used. A number of captured barrels were used and, as a result, the barrel bore became 7.7 cm. A flanged projectile was used as may be seen from Fig. 13.

(b) Description.

The special device 113A, consists of a smooth barrel of 1600 mm. length. The shell unit consists of the shell and the counter-weight, or dud, which are joined by a notched rod of known tensile strength. The propulsion charge, in a cardboard shell case, is placed between the shell and the dud (around the notched rod). Firing takes place through an electrical firing or detonating screw which is built into the dud.

(c) Operation.

After the firing device makes contact, the powder charge is ignited. When enough gas pressure has been built up to break the notched rod, both shell and dud start moving. Both the shell and the dud leave the barrel at the same time so that the latter remains free from recoil.

(d) Assessment.

An initial velocity for the projectile of 650 m/s was attained in firing tests. This was sufficient to penetrate 45 mm. armor (of 120 kg/mm^2 steel) at an angle of 60°. As may be seen in the following table, the dud had a muzzle velocity of 125 m/s and the gas pressure was about 1700 kg/cm2. Within the limits of 10 meters, the projectile flies with enough stability to guarantee this armor piercing performance. The stabilization of the shell is probably due to the manner in which the front guide flange is formed. According to the test stations of the Air Ministry, the same penetrating of armor piercing performances were made

6. SG 113A (7.7 cm. - 4.5 cm.) (d) (Cont'd.)

during actual test firings from an airplane. Figures 14 to 18 inclusive, illustrate the installation of this device in an Hs 129 at Braunschweig, where flight tests of this system were made. The table below gives ballistic and technical data concerning the SG 113A.

General Data.

Caliber	mm.	77/45
Muzzle velocity shell	m/s	650
" " dud	m/s	125
Weight of shell	kg.	1.9

Ammunition.

Type of shell	A.P.	
Weight of shell	kg.	1.9
Length of shell	mm.	140
Weight of explosive	g.	18
Weight of propellant	g.	360
Weight of dud	kg.	10
Total weight of round	kg.	12
Length of round	mm.	530
Type of firing	electric	

Barrel.

Caliber	mm.	77
Length	mm.	1600
Weight	kg.	48
Maximum gas pressure	kg/cm2	1700
Design gas pressure	kg/cm2	2200
Smooth bore		

Weapon.

Weight of weapon	kg.	48
Length of weapon	mm.	1600
Weight of weapon with ammunition	kg.	60

7. SG 116 (3 cm.) (Zellendusche)

(a) Evolution.

During the development of the special device SG 113A, the Air Ministry carried out experiments with an automatic firing arrangement that permitted an airplane, while flying towards and under the enemy airplane, (at 200 m. altitude differential) to make successful attacks. This system included a photo-electric fire control arrangement. Other reports have been written, describing this system which was known as "Zellendusche" or "Showerbath".

The Air Ministry directed Rheinmetall-Borsig to develop a recoilless device, similar to the SG 113A, with a muzzle velocity of 860-900 m/s, 3 cm. caliber, firing a 3 cm. "Minengeschoss" or high explosive shell, with tracer, for use in this system. The device was built in a very short time, by using the barrels of the MK 103 already on hand.

(b) Description. (Figure 19)

The SG 116 consists of the barrel (the MK 103 barrel with slight changes in the chamber) and the breechlock with firing device. The breechlock is fastened to the barrel with the usual locking threads and is kept from turning by a simple spring. The shell unit consists of the 3 cm. "Minengeschoss", a cardboard shell case with the propellant charge, and the counterweight or dud, the latter containing the electric detonating screw that serves as the firing device.

(c) Operation.

When the automatic firing release device operates, the shell unit is fired in the usual way and the shell and dud can be made to leave the barrel simultaneously, hence there is no recoil. Three of these barrels are installed in the aircraft, pointing up and slightly to the rear.

(d) Assessment.

In firing tests, the gun achieved a muzzle velocity of 800 m/s with

7. SG 116 (3 cm.) (Zellendusche) (d) (Cont'd.)

a shell weight of 315 g. and remained perfectly steady while being fired from a pendulum type mount. Air tests gave satisfactory results. The following table contains ballistic and technical data concerning the SG 116:

General Data

Caliber	mm.	30
Muzzle velocity shell	m/s	860
" " dud	m/s	200
Weight of shell	kg.	0.315
Weight of weapon	kg.	28
Length of weapon	mm.	1600

Ammunition.

Type	"Minengeschoss" (H.E.)	
Weight of shell	g.	315
Length of shell	mm.	140
Weight of explosive	g.	72
Weight of propellant	g.	125
Weight of dud	kg.	1.35
Weight of round	kg.	1.8
Length of round	mm.	625
Type of firing	electric	

Barrel

Caliber	mm.	30
Length	mm.	1338
Weight	kg.	23
Length of rifling	mm.	1100
Number of grooves		16
Diameter between grooves		31.0
Width of lands	mm.	3.4 mx.
Type of twist	constant	
Starting angle		8° 30'
Ending angle		8° 30'

7. SG 116 (3 cm.) (Zellendusche) (d) (Cont'd.)

Max. gas pressure	kg/cm2	2800
Design gas pressure	kg/cm2	3600
Weight of weapon	kg.	28 (one barrel only)
Length of weapon	mm.	1600

8. 117 to 119 (3 cm. multi-barrel).

(a) Discussion.

The idea of attaining greater density of fire (shot-shell method) and the method of automatic firing-release by means of the photo cell or similar devices, made the development of multi-barreled guns seem desirable. After considering all factors, it was decided that an interval of about 3 or 4 milli-seconds between shots was most suitable. Such a time interval corresponds to a cyclic rate of about 15000 to 20000 shots per minute.

To achieve simplicity in construction and to use existing ammunition, the barrels and ammunition for the 3 cm., MK 108 aircraft gun were used. The most favored design, as far as structure and space considerations were concerned, was a multi-barrel block containing 7 barrels. In order to get freedom from recoil, as the projectiles shot forward, the block was shot backwards out of a guide which was built into the airplane.

The barrels had an average wall thickness of 5 mm., in order to get as small an outside diameter as possible and to keep down weight. At the top of the chamber where the highest gas pressure occurred, the barrels were fastened together by a sheet metal casing 5 mm. thick, and the interstices were filled with concrete. Thus the stresses of the individual barrels were absorbed by the whole barrel block.

The firing plug was placed behind the shell in each barrel. This plug was made of plastic and had a small firing pin and spring and the connecting wire on the rear surface. Behind this firing plug all the barrels were closed off by a single sheet metal disc which was screwed on. The ignition wires were brought together behind this metal disc and led in a distributor which delivered firing current at a cyclic rate of 20000 rounds.

8. 117 to 119 (3 cm. multi-barrel). (Cont'd.)

In order to achieve an even greater shot-shell effect, 7 of the 7-barrel blocks were mounted on a plate and thus formed a barrel battery of 49 barrels. Unlike the single barrel-block, this barrel battery was not recoil-less. The recoil was absorbed by a short recoil mechanism of buffers.

Further development showed that freedom from recoil could be attained in the barrel-blocks by using a jet-effect so that it was no longer necessary to shoot out the entire single 7-barrel block. Experiments were carried out with a barrel provided with jet and, in order to save weight and keep the diameter down, the caseless shell of nitrated cardboard was used. The first attempts gave good results and complete freedom from recoil, but the events of war prevented completion of the project.

(b) SG 117 (Figure 20).

The weight of the barrel-block, including ammunition, was about 30 kg. Freedom from recoil was achieved by firing the block backwards. This block was installed in either the wings or the fuselage, to fire vertically upwards, firing being initiated by photo-electric cells or other automatic devices. (infra-red, etc.)

After the first shot is fired by the release device, the barrel-block moves backwards, being guided out by suitable barrel-block guides. As the block moves backwards, a contact bar which is fastened to the block and has 7 contacts, consecutively energizes the remaining shells which thus fire in rapid succession. The firing interval corresponds to the velocity of the barrel block as it moves through the guides and this velocity is so worked out that the desired interval of 3-4 ms. is attained.

When using several barrel blocks together an additional tail contact is provided to release the first shot of the next block.

(c) SG 118.

The weight of the barrel-block with ammunition is about 30 kg. This is the same barrel-block as described above except that the instal-

8. 117 to 119 (3 cm. multi-barrel). (c) (Cont'd.)

lation in the airplane is not vertical but horizontal. No closed block-guide is used, but merely guide rails fastened to the under side of the fuselage or wings.

(d) SG 119 (Figure 21).

The weight of this battery with ammunition is about 200 kg. This is a barrel-battery of 7 barrel blocks of 7 barrels each, hence 49 barrels in all. It can only be installed in the fuselage, and the total recoil must be absorbed by the airplane structure. It was specially developed as a shot-shell gun for the fastest new German fighters. The firing interval is controlled by a firing-distributor, which is driven by springs. The release is initiated by means of a push button on the control stick. The barrel-battery moves in recoil against a buffer spring unit with a maximum recoil force of about 6000 kg. The rate of fire was about 1000 to 1200 s.p.m.

9. FH-15 (15 mm.)

This device was invented by a Hungarian Army officer and was developed by the Gustloff Works, Suhl, Thuringia, at the order of the Air Ministry. This device permits firing 7 to 9 15 mm. shells at a cyclic rate of about 25000 rounds per minute. The 7 or 9 shells of 15 mm. caliber are joined in a gas chamber (see Figure 22) which is supplied with propulsive gases from a shell case. After firing, the first shell lying centrally in front of the barrel leaves the barrel. As the first shell leaves the muzzle, the gas pressure in the bore drops; the pressure in the shell chamber feeds the next shell into the axis of the bore so that the free glow of the propulsive gases through the open barrel is blocked. The second shell is then also shot out of the barrel and the whole process is repeated until the shell chamber is empty.

As far as Rheinmetall-Borsig personnel knew, the biggest problem was the proper combustion of the powder, since, in order to avoid too high gas pressure it had to burn in a sort of saw-tooth curve. The propulsive charge was believed to function like a rocket charge. Detailed data about length and dimensions of the device were not known. The barrel of the MG 151 was thought to have been used. Tests were supposed to

9. FH-15 (15 mm.) (Cont'd.)

have shown that the shells had to have two rotating bands, with a second one near the centering rim, since otherwise any wobbling of the shell in the barrel would damage it. The question of using shells with impact fuzes was not settled and was expected to present serious problems. This gun was developed as a single shot, but it was planned to develop it as an automatic.

10. MK 213 (2 cm. 3 cm.) and MK 214 (5.5 cm.) Guns.

(a) MK 213.

As a replacement for the standard MK 108 (3 cm.) gun (which is described hereinafter), studies were just being initiated for the design of the MK 213 gun. The design of this gun was to be radically different and using 2 cm. projectiles it was to have a rate of fire of 1400 spm with a muzzle velocity of 1000 m/s. Using 3 cm. projectiles, it was to have a rate of fire of 1100 spm. The gun weight was to be about 60 kg. This project was cut short by "war events".

(b) MK 214.

This gun was to be a 5.5 cm. gun with a muzzle velocity of about 900 m/s. The gun was to be belt fed and the total round was to weigh about 7 kg., the projectile with 450 grs. of HE, to weigh about 1.8 kg. For experimental purposes, a gun was made up, using parts from the standard German armored-car gun (KWK 39), but 5 cm. instead of 5.5 cm. caliber. Experiments were continuing when "war events" cut the project short.

11. Harp. Fighter's Fist. Bomber Saw.

(a) Harp. (Development by Hasag, Leipzig)

The Harp consists of two rows of 20 unrifled 2 cm. barrels each, which are attached vertically to the side of the fuselage of an airplane, and out of which are fired shells with fin stabilizers. The Harp was supposed to deliver a shot-shell pattern while passing under an enemy

11. Harp. Fighter's Fist. Bomber Saw. (a) (Cont'd.)

airplane. The release was to be actuated by means of an optical device. The individual barrels were recoil-less, in that the powder column behind the shell was fired electrically and burned so that the exhaust of gases was opposed to the ejection of the shell. The 20 barrels were arranged to be jettisonable, after firing. Tests in the air resulted in a satisfactory pattern of hits and sufficient stability. The effect of the 2 cm. mine shell was, however, not great enough, so that the whole development was changed to larger calibers.

As a forerunner of the Harp, a recoil-less single barrel of 12 cm. caliber was installed to fire vertically upwards. The 8.8 cm. Flak shell with incendiary shrapnel was used in this device and freedom from recoil was achieved by firing such a shell containing 300 incendiary pellets, from each end of the barrel at the same time. Flight tests showed insufficient damage effect from the incendiary shrapnel and too low ballistic stability.

(b) Fighter's Fist. (Development of Hasag, Leipzig)

This is a single barrel of 520 mm. length from which an H.E. shell of 5.5 cm. caliber is fired, also using optical actuation. The barrel has rifling and functions both as barrel and shell case since it is shot backwards out of a fixed guide when the projectile is fired in order to eliminate recoil. The muzzle velocity of the shell is about 400 m/s. The external ballistics in firing were satisfactory. The Fighter's Fist development gave promise because of its great effectiveness at the target, its low cost, and the ease of manufacture and installation. Destruction of the plant at Leipzig, by bombing, closed the project.

(c) Bomber Saw. (Development by Lieut. Schlitter of the Air Force)

Schlitter's suggestion was based on a multi-barreled gun which fires an oblique blast either upward or downward, wherein firing is initiated by optical means while passing the target. The first development, called the "whiskbroom", consisted of 60 2 cm. barrels, loaded with H.E. ammunition and fired at a cyclic rate of 20000 rounds per min. The recoil was kept within a limit of 5-6 tons by means of a base plate mounted on springs. The muzzle velocity of 180 m/s was not sufficient to provide suitable stability when firing at an angle. The 2 cm. caliber

11. Harp. Fighter's Fist. Bomber Saw. (c) (Cont'd.)

was also discarded because its damage effect was insufficient. Later developments called for 60 3 cm. barrels on a sprung platform. The Bomber Saw never got beyond the experimental stage for the usual reason, i.e., "events of the war".

12. Guns in Service.

(a) The MG 131 - 13 mm.

This gun is a recoil-operated gun with a fixed central bolt. It consists of: (1), barrel with recuperator and casing; (2), bolt; (3), housing; (4), buffer; (5), feed; (6), magnetic trigger with (7), electric charging or (8), air charging; (9) hand trigger with (10), hand charging; and (11), belt. Further description and details, with the exception of the data table, are not given herein, since the design of this gun is old and many samples have been sent to the United States. The following table contains ballistic and technical data concerning the MG 131.

Caliber	cm.	1.3
Muzzle velocity	m/s	750
Weight of shell	kg.	0.035
Length of shell	mm.	42
Weight of explosive	kg.	0.0035
Weight of propellant	kg.	0.007
Weight of round	kg.	0.076
Length of round	mm.	105
Type of detonation	electrical and mechanical	
Length of barrel	mm.	550
Weight of barrel	kg.	3.6
Maximum gas pressure	kg/cm2	3300
Design gas pressure	kg/cm2	3600
Weight of gun with electric charger	kg.	19.5
Length of gun	mm.	1185
Type of feed	belt, right or left feed.	
Weight of a link	kg.	0.009

12. Guns in Service. (a) (Cont'd.)

Weight of belt with 100 rounds	kg.	8.5
Recoil distance of bolt	mm.	210
Weight of bolt	kg.	1.0
Recoil distance of gun	mm.	8
Recoil force	kg.	450
Type of charging	electric, pneumatic or manual	
Type of firing	electric or manual	
Type of detonation	electric or mechanical	

(b) MK 101 (3 cm.) cannon.

This gun is recoil-operated and has a centrally fixed bolt. The monobloc barrel is mounted so as to be movable in the gun housing and when the gun is fired, the barrel moves back, being rigidly fastened to the bolt. A muzzle brake, to reduce recoil, is attached with bayonet locking threads so that it can be quickly changed. After unlocking, the bolt slides further back under the pressure of the sling lever (Schleuderhebel) and ejects the empty case downward. The recoil of the bolt is limited by a buffer built into the gun housing. As the bolt moves forward a new shell is fed in and after the bolt action is completed the shell is fired mechanically.

The feed is from above either by 6 round magazines or 30 round drums. A disintegrating continuous belt feed was also developed, but was not put into actual use. The gun is charged by compressed air, which pulls both the barrel and the bolt back at the same time. The trigger is actuated by a solenoid.

To cut down recoil, the gun is arranged to have recoil movement. The recuperator mechanism consists of spiral compression springs. a shoe friction brake is built in. The individual parts of the gun are one piece forgings. The gun was in serial production but was eventually replaced by the MK 103 and MK 108 described hereinafter. The following table contains technical and ballistic data concerning this gun:

Caliber	cm.	3
Muzzle velocity	m/s	860
Weight of shell	kg.	0.33

12. Guns in Service. (b) (Cont'd.)

Weight of propellant	kg.	0.106
Muzzle energy	mt.	12.5
Weight of round	kg.	0.78
Type of detonation	mechanical	
Length of barrel	mm.	1350
Weight of barrel	kg.	40
Maximum gas pressure	kg/cm2	3300
Rate of fire	Sch/min	260
Weight of gun	kg.	180
Type of feed	magazine with 6 rounds	
Type of firing	Drum with 30 rounds solenoid	

(c) MK 103 (3 cm.) cannon

This is a blow-back operated gun with a fixed central flap bolt mechanism. It was made in two forms: as an engine-mounted gun with a telescoped liner and blast tube, and as a nose gun with a monobloc barrel. The construction was the same except for the parts where the barrel was mounted.

The barrel is mounted so as to be movable in the gun housing and has a muzzle brake to cut down recoil. It has a recuperator mechanism consisting of spiral compression springs and has a shoe friction brake. The barrel is set into the breech block by means of bayonet locking threads. The breech block has inserted hardened bearing surfaces in the rear legs for the bolt action.

The breech consists of the breech block and the bolt slide. In the breech block are the electric firing mechanism, the feed lever, and the bolt flaps. The current feed for the firing mechanism is attached to the bolt slide. Bolt grooves are milled into the right and left sides of the slide and these actuate the flap mechanism in the breech. The catching face is on the under part of the slide.

The gun housing is made of sheet metal stampings in 2 halves. The breech guide rails are welded in. The two cylinders for the brake mechanism are on the right and left of the gun housing. Beneath the gun housing is the spring housing with the bolt recuperator spring, the charging device, and the electric-pneumatic trigger. The gun housing is

12. Guns in Service. (c) (Cont'd.)

closed at the back by a cover plate. The sheet metal belt feed is bolted on top of the gun housing and fastened at the back with a quick opening connector. The feed is driven by a cam lever which is actuated by the breech block as it moves back. The moving parts of the feed are interchangeable for left or right. Since the charging mechanism only moves the bolt, a special air charging mechanism also switched on the feed while charging. The belt is of the link disintegrating type.

In the model built as a nose gun, the exchange of barrels is effected from the front end, while with the engine gun, the barrel must be taken out from the rear of the engine. A muzzle brake cannot be used with engine installations. Hence reinforced barrel recuperator springs and friction brakes must be installed.

Experiments to increase the cyclic rate resulted in rates of fire of over 600 rounds per minute but the life of various parts proved to be critical at this rate. The experiments had not been completed when the war ended.

The following table contains ballistic and technical data concerning this gun:

Caliber	cm.	3
Muzzle velocity	m.s	860
Weight of shell	kg.	0.33
Weight of propellant	kg.	0.106
Muzzle energy	mt.	12.5
Weight of round	kg.	0.78
Type of detonation	electric	
Length of barrel	mm.	1350
Weight of barrel	kg.	23
Max. gas pressure	kg/cm2	3300
Rate of fire	Sch/min.	420
Weight of gun	kg.	140
Type of feed	Disintegrating link belt, right or left	
Type of firing	Electro-pneumatic	
Maximum recoil force	tons	2
Impulse	kg.s	42

12. Guns in Service. (Cont'd.)

(d) MK 108 (3 cm.) cannon.

This gun is built on the mass-bolt system and was to be used for installations in fuselages, wings, and engines as well as experimentally in rotating and multiple mounts (turrets). The mass-bolt system (Massenverriegelungssystem) permitted the simplest type of construction and hence the cheapest manufacture of individual parts. The barrel is screwed tightly into the gun housing and pinned. The front end of the barrel is threaded for mounting the flash hider. The gun housing is made of two sheet metal stampings and has lugs for attaching the various action assemblies.

The piston for the charging device is in the frontal plate of the housing. In the middle of the gun housing, on top, is the opening for the belt feed and the lower part of the feed mechanism is welded into the opening. At the back end of the gun housing are the lugs for the base plate and on top of the housing are lugs for attaching the feed and the electro-pneumatic trigger. On the left side of the housing are fastening lugs for the electric firing or switch contact. The feed consists of sheet metal stampings with inserted guide rails to take the belt feed slide and bushings for the feed levers. On the back end of the feed housing is the quick acting bolt (Schnellverschluss). The feed may be changed from right to left hand by changing individual parts.

The steel belt is made up of links (stamped manufacture) and disintegrates after the empty case has been pulled back into it and ejected from the gun housing. In order to insure trouble-free disintegration of the belt, a disintegrating device was supplied for either right or left hand operation and fastened to the feed cover.

The electro-pneumatic trigger is actuated by a moving piston. The trigger bar is mounted in a buffer with two circular springs. The contact bar on the left side delivers the current to the firing device in the bolt. It can be replaced by a switch contact, which will indicate the automatic charging in the case of mis-fires, and a rounds counter.

The bolt (Verschluss) is made of a single forging. It has two cams running the whole length of its top side which feed the belt. On top of the head of the bolt is the self-activating leaf-spring ejector. Experiments have been made with an ejector with spiral compression

12. Guns in Service. (d) (Cont'd.)

springs. This design was to be put into serial production after thorough tests. The front side of the bolt head is provided with an interchangeable hardened steel liner.

The air charging device actuates the bolt and is located under the barrel. The moving piston is fastened to the front side of the housing while the cocking cylinder actuates the bolt. The cocking cylinder is moved forward again by a recuperator spring fastened to the cover. The bolt recuperator springs are overlaid spiral compression springs. The bolt buffer springs consist of two columns of circular springs with a buffer piece in front.

When the trigger is pulled, the bolt is snapped forward by the pressure of the bolt recuperator springs and moves half a belt link so that a shell is lined up with the barrel. This is then shoved out of the belt into the barrel by the bolt head. The electric firing takes place 15 mm. before the dead end position of the bolt. The case is forced back by the gas pressure, along with the bolt, and the ejector pulls the case back into the empty belt link. After the ejector releases, the case remains in the belt. The bolt moves farther back and moves another half belt link. The recoil is limited by the bolt buffer. Since the bolt, in normal operation, does not strike very hard, either forward or back, it may be said to float back and forth.

Experiments with increasing the cyclic rate resulted in rates of over 1000 rounds per minute. These experiments were not completed, since various moving parts, such as bolts, recuperator mechanism, buffer and belt were breaking down. After thorough tests the model was to go into serial production.

The high cyclic rate was achieved by making the bolt lighter and reinforcing the bolt recuperator mechanism, and by installing spiral compression springs instead of circular springs in the buffer.

Several samples of this cannon, together with ammunition and accessories, have been sent to the United States. The following table contains ballistic and technical data concerning the MK 108 cannon:

Caliber	cm.	3
Muzzle velocity	m/s	500

12. Guns in Service. (d) (Cont'd.)

Weight of shell	kg.	0.33
Weight of propellant	kg.	0.026
Muzzle energy	mt.	4.65
Weight of round	kg.	0.48
Type of detonation	electric	
Length of barrel	mm.	550
Weight of barrel	kg.	8
Maximum gas pressure	kg/cm2	3100
Rate of fire	Sch/min	650
Weight of gun	kg.	60
Type of feed	Disintegrating links, right or left	
Type of firing	electro-pneumatic	
Maximum recoil force	tons	2
Impulse	kgs.	21.5

(e) 3.7 BK cannon.

The 3.7 cm. BK was developed from the automatic Flak gun 3.7 cm. Flak 18. It was primarily intended for use against armor and was installed in the HS 129 and Ju 87. For Flak use, the gun was equipped with a 6 round clip feed. For use in aircraft the feed was changed so that the loading device could take two clips of 6 rounds each. The clips could be fired in single shots or in bursts. Reloading was done on the ground. The trigger had to be actuated by remote control when the gun was used in an airplane. An electro-pneumatic trigger mechanism was developed for this purpose. The original recoil mechanism was adaptable for use in aircraft with only very slight changes. The following table contains ballistic and technical data concerning this gun:

Caliber	cm.	3.7
Muzzle velocity	m/s	860
Shell weight	kg.	0.570
Weight of propellant	kg.	0.218
Muzzle energy	mt.	22.5
Weight round	kg.	1.46
Type of detonation	mechanical	
Length of barrel	mm.	2106
Weight of barrel	kg.	68

12. Guns in Service. (e) (Cont'd.)

Maximum gas pressure	kg/cm2	2400
Rate of fire	Sch/min	140
Weight of gun	kg.	275
Type of feed	Clip feed, from left side	
Capacity of clips		6 rounds
Type of firing	electro-pneumatic	

(f) 5 cm. BK cannon (See Figure 23).

At the request of the Ordnance Bureau of the Air Ministry, the tank gun KWK 39 was developed for use against heavy bombers. The 5 cm. BK consists of the old KWK 39, with slight alterations to the barrel, breech and recoil mechanism; a newly developed feed; the incorporation of electric firing and detonating.

The magazine, built around the gun, was driven electro-pneumatically and held a total of 22 rounds. These could be fired singly or in continuous fire. Inside the magazine is an endless shell feed chain that can be reloaded by hand, even if only a portion of the 22 rounds have been fired. To cut down recoil, the gun was equipped with a sieve muzzle brake. This gun was installed in the ME 410 fighter. Its dimensions were such that it could be put in the forward bomb bay without any change to the external shape of the airplane. About 300 of the devices were built up to February 1944. Production was stopped on order of the Air Ministry because the ME 410 was not fast enough. The following table contains technical and ballistic data concerning this gun:

Caliber	cm.	5.0
Muzzle velocity	m/s	920
Weight of shell	kg.	1.35
Weight of propellant	kg.	0.9
Muzzle energy	mt.	73
Weight of round	kg.	4.1
Type of detonation	electric	
Length of barrel	mm.	3.040
Weight of barrel	kg.	245
Gas pressure	kg/cm2	2500
Rate of fire	Sch/min	45

12. Guns in Service. (f) (Cont'd.)

Weight of gun	kg.	350
Weight of gun installed	kg.	540
Type of feed	drum magazine	
Capacity of drum	22 rounds	
Barrel recoil	mm.	335
Type of firing	electric	
Type of brake	fluid	

(g) 7.5 cm. BK cannon.

The 7.5 cm. BK was developed from the 7.5 cm. anti-tank gun Pak 40, as a measure of expediency. This gun was chiefly intended for use against heavy armor such as tanks and other armored vehicles. In other words, it was to be a flying anti-tank gun. Slight changes were made in the barrel and the recoil mechanism and the breech was changed over to electric firing. The shell feed was made automatic with a drum magazine for 12 rounds. Feed and handling of the shell was done electro-pneumatically. The shell was taken out of the drum and shoved in front of the open barrel by a parallelogram-like loading tray. From there, the weight of the shell slid it into the chamber. After the breech was automatically closed, the shell was electrically fired.

The gun was installed in the Henschel fighter, HS 129. The layout was so managed that the drum magazine was located in the fuselage. The barrel, which had a sieve muzzle brake, protruded from the nose about 1 meter. Up until the end of 1944, about 30 of the guns were finished and were used in the HS 129 fighter during the early part of 1945 on Germany's eastern front. The following table contains ballistic and technical data concerning this gun:

Caliber	cm.	7.5
Muzzle velocity	m/s	730
Weight of shell	kg.	6.8
Weight of propellant	kg.	2.45
Muzzle energy	mt.	185
Weight of round	kg.	11.6
Type of detonation	electric	
Length of barrel	mm.	3100
Weight of barrel	kg.	450
Gas pressure	kg/cm2	2800
Rate of fire	Sch/min	30

[redacted]

12. Guns in Service. (g) (Cont'd.)

Weight of gun	kg.	595
Weight of gun installed	kg.	700
Type of feed	drum	
Capacity of drum	12 rounds	
Barrel recoil	mm.	915
Type of firing	electric	
Type of brake	fluid	

13. Conclusion.

It can be concluded from the wide variety of guns under development, that Germany was not entirely satisfied with the automatic aircraft guns and cannon which were used in the actual service. The one outstanding point was the relatively low muzzle velocities used. This was apparently beginning to get considerable attention as was also the rate of fire. The sentiment was expressed that the Air Ministry was beginning to be reconciled to the idea of frequent barrel change (as low as 350 rounds) if muzzle velocity and rate of fire could be materially increased. The one point upon which all of the German personnel were thoroughly in agreement was the value of the so-called "Minengeschoss", or thin case projectile with heavy H.E. loading, especially in the 5.5 cm. calibers.

Prepared by:

Dr. L. H. Glassman
Technician