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GERMAN GUIDED MISSILE RESEARCH

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COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

S E C R E T

GERMAN GUIDED MISSILE RESEARCH

Reported by

Mr. N. COLES.	MAP
Mr. R.J. LEES.	MAP
Mr.P.R. OWEN	MAP
Mr. J.H. WHITAKER	MAP
Mr. E.H.COOKE-YARBOROUGH	MAP
Maj.. R.A. FELL	MAP
Lt. (JG) ROBERTS	USNR.
Lt. KOHLENBERG	Sig.C.,Paris
Capt. J.W. GILES.	A-2,HQ,USAFE

CIOS Target Numbers 4/288 & 6/144
Rockets & Rocket Fuels.
Jet Propulsion.

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
G-2 Division, SHAEF (Rear) APO 413.

S E C R E T

OUTLINE OF REPORT.

I. INTRODUCTION.

1. Terms of Reference of CIOS Team 367.

The "Terms of Reference" of CIOS team 367 were the study of Guided Missiles, particularly with respect to their design, and design problems encountered. Further, to study any basic research whose fundamental principles were applicable to the solution of Guided Missile problems, and to study the design of components which were used for Guided Missiles.

2. Exclusions.

Before investigating any target or target areas, the team made a survey of those Guided Missile projects which were either fully exploited, or which were reported to be in the process of exploitation. The following exclusions were decided upon. The V-series of weapons were considered to be in the process of exploitation by adequate scientific personnel to exclude further study by this team, as was Rheintokter, manufactured by Rheinmetal-Borsig. It was further decided that the field of Proximity Fuzes had been exploited by various organizations such as ALSOS, OTIT, and other CIOS teams to such an extent that further study would not be economical except to study those Proximity Fuzes which were associated with actual guided missile targets or to study any basic research encountered whose ultimate application would be Proximity Fuzes.

3. Additional Reports of Associated Investigations.

Many targets were investigated which were only partially Guided Missile targets, and where it was considered that the investigating personnel of this team was capable of thoroughly investigating and exploiting the other projects, a complete investigation of the target was carried out. These associated projects are listed below, and the reports involved are indicated. -

a. The wind tunnel installation at Kochel was investigated by Mr. Paul R. Owen of R.A.E. and a report of this investigation will be issued as an R.A.E. report, a copy of which will be sent to CIOS and to A-2, Electronics Intelligence, USAFE (REAR.

b. A battery which was reported to have very high performance, manufactured by "Martins" on the Elbe, is to be tested under the supervision of Capt. J. W. Giles of A-2, Electronics Intelligence, USAFE, and a report will be submitted to CIOS and to A-2, Electronics Section, USAFE (REAR).

c. An infra-red homing device manufactured by Kepka works of Vienna, the only model completed is now being tested by RAE and TRE, and a report on their findings will be submitted by Mr. R J. Lees of TRE to CIOS and to A-2, Electronics Intelligence Section, USAFE, (REAR).

OUTLINE OF SECTION II.

II. GENERAL DISCUSSION OF GERMAN GUIDED-MISSILE PROJECTS :

A. A-Series of Missiles.

B. V-Series of Missiles.

C. The Henschel Series of Guided Missiles.

D. The X-Weapons Guided Missiles.

E. Flak and Ground Guided Missiles.

F. Unguided Missiles.

G. Development Missile Projects.

II. GENERAL DISCUSSION OF GERMAN GUIDED-MISSILES PROJECTS.

1. Appendix 1 to this report is a chart which lists Guided Missiles. This chart is probably not complete but lists most of the types in the German war effort.

A - Series of Missiles.

The complete A-series of weapons had 16 models designated A-0 through A-15. They are all associated with developments up to the V-2 or developments of improvements of the V-2 as it is known to have been used.

The first six A-series models resulted in the V-2 weapon :-

Ao - Was the first attempt to develop a rocket motor whose thrust was sufficient to propel a 13.75 ton projectile. The Ao was never capable of sufficient thrust, however, through the study of the Ao, A1, A2, the small version of the V-2 was developed and became the A5.

A1, A2 & A3 - Were additional attempts to develop the thrust units and fuel for a V-2.

A4 - Development completed after the A5 had been successful. The V-2 was the production model of the A4.

A5 - Was a small version of the V2. It was the first successful attempt at large scale, long range rocket propelled projectiles by Germany. Through the experience gained from the A5 and its predecessors Ao, A1, A2 and A3, the A4 (V-2) was finally perfected.

A6, A7 & A8. - Were experimental developments of the A4 (V-2) with the addition of wings so that the range could be incresed.

A9 - Was the result of work on the A6, A7 and A8, and was a V-2 with wings so that instead of following a normal Hyperbolic trajectory, it would glide to earth after reaching a maximum height from the rocket propellent. Its range was increased to about 600-km or about 375 miles. Thus, the projectile could be launched well inside Germany, itself, and still reach England.

A10 -Was an experimental model of an additional thrust unit which was to be fastened to either the A4 (V-2) or the A-9 to give an additional range. It was to carry its own fuel, and

- when the fuel was completely burned the unit was released, at the same time starting the normal thrust unit in the A4 (V-2) or A9.

A-11, A12, A13 & A14 -- Were development models of the A9 - A10 series attempt to produce a long range rocket projectile for attacks on the North American continent. The range strived for in these and the A15 model was 3500 miles.

A15 - Was to have been a 3500 mile range projectile using the A9 and A10 developments. This project probably never progressed beyond the drawing board stage.

B. V-Series of Missiles.

The V-series of missiles, four known types, two being used by the end of the war in Europe, have been covered by large numbers of technical investigation teams whose reports are available; therefore, it was decided that CIOS Team 367 would not make a complete Technical Investigation of them. However, all guided missile work in Germany was related to the developments of these and the A-Series weapons since they were projects which required much research work, the results, in many cases, being applicable to all jet and rocket propulsion problems. Further, the testing of most Guided-missiles was the responsibility of the scientific group at Peenemünde, and their evaluation and ideas were circulated through most of the scientific and development personnel of Germany.

V1 - Was a jet propelled-ground-to-ground missile which was aerodynamically stabilized. It flew at sub-sonic speeds and could be overtaken by an airscrew propelled aircraft. It was launched either from the ground, or from a "mother-plane." Its maximum range was about 350 km, although this depended on wind. The warhead was 830 kg for a range of 250 km but was later reduced to 500 kg for longer ranges up to 350 km. Maximum fuel load was 1000 liters. Speed between 620 and 650 km/hour. Maximum altitude 2500 meters but normal operating altitude was 1000 meters or lower, depending on cloud cover and wind conditions. Overall length 25-ft 4½-ins, wing span 15-ft. The V-1 was gyro-stabalized and compass guided. Except in experimental launchings, no radio or other external control was used. The cut-off time was regulated by the turning of a small airscrew on the nose of the missile.

V2 - Was a rocket-propelled ground-to-ground missile which was not aerodynamically stabilized. It flew at supersonic speeds. The missile was 45-ft 10-in long and and 4-ft 5½-inches in diameter at the maximum body diameter; however. the tail fins were 11-ft 8½-inches from opposite tips. At the time CIOS team 367 was at Nordhausen, there were evacuation teams moving complete V2 units back to England (and the U.S.) for study, and firing trials; therefore, very little detailed study was made of the equipment. However, in the Technical Analysis Section of this report is a short section on Radio Control of V2. The V2 missile was radio-controlled, especially in its early use. It had gyro-control and time-measurement control.

V3 - Was a larger version of the V1 with an incendiary warhead instead of the HE as normally used. Very little information is av ilable concerning V3 control systems.

C. The Henschel-Series of Guided Missiles.

Henschel's guided missile program was under the scientific direction of Professor Wagner. The series of guided missiles includes about 27 models for a wide variety of purposes and using several methods of control. The models will be listed below, with a brief explanation of their characteristics and reference to their control methods. A more complete explanation of their electrical and control equipment is given in the Technical Analysis Section of this report, The missiles are listed according to their serial numbers so that the evolution of their control systems can be logically followed.

HS-293-V2 - First experimental models 1940/41. Glider without rocket motor. Standard control system employing potentiometers. Lateral control by flaps, elevator control by engine unit. No rudder. Receiver Strassburg E-30. Filter and DC-Amplifier. (Aufschaltgerät Strassburg) Power supply by batteries for 24 and 210-volts. Current approx. 30 Amp. Number of valves: 27. High frequency: "Kehl" - frequency (Approx. 6-m band) Control frequencies: 1000, 1500, 8000, 12000 cycl/sec. Control-stick-contact-frequency:. 10 cycl./sec.

HS 293 V3 - Improved experimental model 1941. Rocket motor attached. Wiring and separate apparatus combined in unit. (SAG) 24 volt-supply by accumulator. 210 volts converter. Production begun.

HS 293 Ac - Production model 1942. Improved 293 V3. Later equipped with relays instead of DC-Amplifier. Electric damping system by relays. Supplementary equipment for remote control by wire was available.

HS-293-A1 - Improved production model 1943. Receiver Strassburg E-230 with relays in output stage. DC-relays-amplifier ASG 230 Universal connecting unit SAG 230. Number of valves reduced to 12. Total amount of 293 V2 - A1 built is approx. 12,000.

HS-293-A2 - Latest production model 1944. New simplified control system. Control-stick-contact-frequency, lateral: 16 cycl. elevator: 5 cycl. Lateral control: new 16 cycl. filter and new potentiometer (6500 Ohms), Wagner-flaps. For elevator control Wagner-flaps were used which were operated by magnets energized directly from the receiver relays. DC-gyro. Forerunner of 298/117 controlling system. Ready for production, but stoppdd by air ministry.

HS-293-B. - This designation does not refer to a special glider model, but indicates employment of a wire control system which was started in 1941. Upon completion of this development, all models HS-283 to HS-296 could be controlled by either radio or wire. For this purpose the receiver E-230 had to be charged for the receiver E-237 (Duisburg) and in the carrier plane the transmitter FuG 203 or 206 had to be replaced by the transmitter FuG 207 (Dortmund). Also two coils had to be attached to the glider and two more to the carrier-plane. Built as supplementary equipment.

HS-293 C1-3 - Glider was small edition of HS-294. Production only in small quantity for experimental work and for testing new control systems in 1942/43 such as the system 293-E, 293-A2, etc.

HS-293-D. - Experimental type. Glider like 293 but with television equipment. A small number was produced, trials being carried out in conjunction with Forschungsanstalt der Reichspost and Fernseh A.G. Berlin 1942-44. Result: Prof. Wagner preferred "Fevi."

HS-293-E. - Model for a new remote control system based on a turn-coil instead of potentiometers. Development started in 1942. Trials with glider 293-C. Plan then given up in 1943 in favor of a new potentiometer control system.

HS-293-F - Design of a tail-less glider. Modified controls of 293-A not built.

HS-293-G - Experimental type. Glider and control system similar to 293, but capable of vertical as well as horizontal flight path, thus possessing the characteristics of HS-293 and of the "Fritz X" (Dr. Kramer). For this purpose a special gyro was constructed, which could be tilted over 90 degrees from vertical to lateral axis. Ten models built in 1942, then work stopped by air ministry in favor of "Fritz X."

HS-293-H - Glider 293 Al for use as anti-aircraft weapon. Special radio equipment used for remote control of fuze by means of 5th control-channel. Standard type 293-A-1 could be converted to a 293-H by exchanging receiver E-230 with E-230 H/I and by attaching a special relays box. Small quantity built in 1943/44 by conversion and use of supplementary equipment.

HS-293-I - Like 293-H but different amount of explosives. Only planned 1943.

HS-294-A - Special model combining glider with torpedo. Controls like 293-A-1 but special fuze devices for blowing off fuselage rear section and wings as soon as body touches water surface, fuselage front section then cruising as torpedo under water. Small quantity built for experimentalpurposes 1941-43. (Largest type designed by Prof. Wagner).

HS-294-H - Like 294-A but equipped with AEG-controlling system. Only planned 1942.

HS-295 & HS-296. Modifications of 293-A with the same electric equipment. Only different fuselage front section and amount of explosives. Small quantity built 1942/43.

HS-297 - Special model. Anti-aircraft weapon for fighting planes from the ground. First planned in 1941 but rejected by air ministry as being a defence weapon. In 1943, urgently requested and therefore replanned on large scale with the designation 8-117.

HS-298 - Special model. Anti-aircraft weapon carried by fighters or bombers. First planned in 1941 but rejected by air ministry, only work on receiver E-232 (Colmar) being carried on. In 1943 urgently requested and therefore replanned on large scale production basis. New controlling

- system similar to 293-A-2 but simplified. Power supply by generator with airscrew. Additional electric distance-meter for special fuze. Experimental series since 1944, mass-production ready. Smallest type designed by Prof. Wagner. (Competitor to Dr. Kramer's "X4").

8- 117 - ("Schmetterling"). Continuation of design HS-297. Special model launched from the ground for fighting aircraft. Controlling system and electric equipment like HS 298 but affording several additional facilities such as igniting system for launching-rockets, speed-regulator, special control-motor for gyro, etc. Experimental models begun in 1944. Special production planned for 1945 on large scale as "Führer-Notprogramm." (Competitors: Wasserfall, Rheintochter and Enzian; but 8-117 was the simplest design requiring the smallest amount of energy.

8-117C - Development of 8-117 in autumn 1944. Equipped with receiver E-232 (Colmar)and distance-meter "Kakadu" or "Fox"

8 -117 A-1 (A-2) - Production model. Latest model of 8-117 in March 1945. Type ready for production. New developments: Receiver for 6-m - band or decimeter-band (E-232 a/b Colmar or Strassburg E-230/3 or Brigg E-531 Distance-Meter: Kakadu, Marabu, Fox, or Meise. Pilot-transmitter "Rüse" for radiolocation. Automatic detonation when control-system fails. (Additional homing-apparatus planned)

8-117-H - Modification of 8-117 to be carried by planes as anti-aircraft weapon. Improvement of the 293-H idea with the advantage that the 8-117-H posses a rate of climb. Controlling system and electric equipment resembling 298.

Late experimental types :

HS-293-V4 - Experimental model 1943/44 based on 293-A but elevator engine replaced by magnets and Wagner-flaps.

HS-293-V5 - Experimental model 1944 resembling 293-A but containing alterations for use by jet-propelled carrier-planes: Electrical features like 293-A-2.

HS-293-V6 - Experimental model 1944 like 293-V5 but with electric controlling system of 298.

HS-293-V8 - Experimental model 1944 like 293-A1 but equipped with receiver E-531 (Brigg) for testing the decimeter system "Kogge."

This list does not completely cover all experimental and production types, but it contains all the outstanding modd which are of any interest because of their controlling system and electric equipment.

D. The X-Weapons - Guided Missiles.

The X-weapons were known to be in the process of being investigated at the time CIOS team 367 was going to Germany, consequently no complete technical investigation was carried out. The X-Series of guided missiles was designed by Dr. Kramer of Ruhrstahl A.G., and were used in combat with some success. The X-Series, like the Henschel Series, were designed for a variety of purposes.

X1 - Primarily an Air-to-Ground (sea) missile also known as Fritz-X or PC-1400-X. It was designed for either radio (Strassburg-Kehl) or wire control, and was adapted for launching from normal aircraft bomb shackles. Length 10-ft 8-inches. Wing Span 4-ft 4-inches. No propulsion unit was used and the speed was sub-sonic (280 meters per second maximum flying velocity). Range 5000-meters.

X2 - Primarily an Air-to-Ground (sea) missile. It was very similar to the X1 but designed for higher velocity (310 meters per second Maximum flying velocity) but still sub-sonic. Length and span same as X1. Length 10-ft 8-inches. Wing span 7-ft 4-inches. Range 5000-meters. Used Radio or wire control. None produced. No propulsion unit.

X3 - Primarily an air-to-ground (sea) missile. It was a super-sonic version of the X1 or X2. (400-meter per second maximum flying velocity). Length 12-ft 2-inches, wing span 4-ft 2 inches The X3 has swept back wings and a small tail compared to the X1 and X2. Radio or wire control. No propulsion unit. None produced.

X4 - Primarily an air-to-air missile. Its speed was sub-sonic (240 meters per second) using 3 BMW, 110 kg maximum thrust, liquid rocket propulsion units at the tips of its three wings. Length 6ft 3-inches . Wire and gyro control was used. Operating range 2000-meters approximately. None produced.

X5 - Primarily an air-to-ground (sea) missile. Only planned, none built. Designed as a super-sonic (maximum speed 400 meters per second). Wire or radio controlled missile. Range 10 to 15 km. Length 15-ft 5-inches. Three symmetrically spaced wings. No propulsion unit. Uses A.P. warhead.

X6 - The X6 is exactly the same as X5 in all details except that a H.E. warhead has been fitted. None produced.

X7 - Primarily a ground-to-ground, or ground-to-air missile; is also known as Rottkappehen. A small missile, length 32-inches, span $21\frac{1}{2}$-inches, wire-controlled. Uses 2 WASAG dry powder propulsion units. Range 1000 meters. Speed sub-sonic (100 meters per second), Produced in small quantities.

E. Flak & Ground Guided Missiles.

This classification pertains primarily to ground-to-air missiles which were designed for air-combat and their guiding and homing devices are of special interest. It is to be noted that these missiles were designed by established research agencies (with the exception of Komet 2) and represent the best developments in propulsion, guiding and homing systems. There is a separate field of study involving homing devices and a third involving proximity fuzes, and, since a homing device can be employed in several, if not all of the following weapons, those encountered by CIOS team 367 will be separately considered under the Technical Analysis Section of this report.

ENZIAN - Designed by Dr. Wurster of Holzban Kissing A.G., and constructed by Messerschmitt. There were five models. Models I,II, III and IV will be considered together, and Model V separately.

MODELS I,II, III,IV. - These models, also known as E1, E2, E3 and E4, are all very similar in mechanical construction, all being designed for sub-sonic speeds. Models E1, E2 and E3 - speed 240 meters per second, and E-4 - speed 300 meters per second. Length 13-ft 2-inches; span (counting body) 13-ft 2-inches. A complete technical analysis of Enzian, including flight test analysis, is included in the Technical Analysis Section of this report. The control system was radio(ground), radar or other homing head. A discussion of the propulsion units and their propulsion problems is in the Technical Analysis Section.

MODEL V. - Also known as E-5, was a super-sonic ground-to-air missile (maximum speed 660-meters per second). The wings were smaller (7-ft 10-inches), while the length is greater than E1 to E4 (17-ft 1-inch). However, four swept-back wings are provided symmetrically spaced around the body of the missile. The propulsion units, aerodynamics and control mechanism is discussed in the Technical Analysis section of this report. The guiding and control system was in an early stage of development, and would probably have been a homing device,perhaps infra-red.

WASSERFALL - Also known as C-2 is a ground-to air missile and is small V-2. It is very large for a flak rocket and was considered to be too big and expensive to be of practical value by some German research scientists. It was 25-ft 10-inches long with a wing span of 9-ft 5-inches, having four wings spaced symmetrically about the body of the missile. This missile is completely discussed in the Technical Analysis Section. Its control system was primarily by radio (Kehl-Strassburg) with special apparatus for ground control. This special equipment is necessary since the C-2 missile is launched vertically and must be brought into colinearity with the target by a pre-complited course and system of movements. This is accomplished by the "Einlenk Gerät" which is fully discussed. Wasserfall had a maximum range of 18 km. Total explosives 305-kg. None produced for combat.

RHEINTOHTER - Two models I and III are known to have been developed by Rheinmetal-Borsig :

MODEL I - Was a super-sonic missile (maximum speed 360 meters per second) develeped by Dr. Hennies of Rheinmetal-Borsig. It was 20-ft 7-inches in length and had six symmetrically spaced wings measuring 7-ft 2-inches, from tip to tip of opposite wings. The wings and tail were well swept back. Propulsion was by one Rheinmetal-Borsig solid fuel jet engine mounted in the body of the missile. Range 12-km. Altitude (maximum) 6 km. Warhead 150-kg.

MODEL III. Model III was a smaller missile than Model I, and did not include separate tail surfaces. It was a super-sonic (maximum speed 419-meters per second) missile, using two externally mounted propulsion units burning solid fuel. This unit was constructed by Rheinmetal-Borsig. The missile was designed by Dr. Hennies. Length 16-ft 5-inches. The missile has four symmetrically spaced wings located well back near the end of missile. The wings are well swept back. Wing span 7-ft. 3-inches. This missile was not studied by CIOS team 367 since it was known to be adequately covered by other technical investigation teams.

KOMET 2. - A ground-to-air jet-steered missile designed by Helmuth Rogge but never constructed. Length 4-ft 2-inches. No wings. This missile isndescribed in the Technical Analysis Section of this report. KOMET 2 is of General interest only, and is not of sufficient technical value to merit further consideration.

FUERLILLE - This ground-to-air missile was built in two models - F-25 and F-55 by LFA Braunschweig, designed by Dr.Braun:

MODEL F-25 - Was a sub-sonic missile (220 meters per second) which was never produced. It was designed to use a solid fuel propulsion unit constructed by Rheinmetal Borsig. Length 6-ft 8 inehes. Wing Span 3-ft 8-inches.- Two wings. Control surfaces on wings and tail. No warhead or explosive charge was included in its original design. The control method was not decided upon, although gyro stabalization was used.

MODEL F-55 - Was a super-sonic missile (maximum speed 400-meters per second), which is much larger than the F-25. The F-55 refers to a missile whose body diameter in 55-cms, while the F-25 has a 25-cm body. F-55 is 15-ft 9-inches long and has a span of 8-ft 2-inches . They were never produced in quantity. An auxiliary launching propulsion unit was used which burned solid fuel, while the main internal propulsion unit was a liquid fuel jet propulsion unit model SG-20 manufactured by Conrad. It was proposed to use Gyro and radio control, but in the experimental models only gyro control had been used.

BV-143 - Was an aerial torpedo glider designed by Dr. Zisker of Blohm and Voss. It was designed specifically as an air-to-surface missile or a liquid fuel rocket powered glide bomb. The flight path was a slow descent to a fixed level a few feet above the surface of the sea, and then to travel along at a fixed height until it strikes the target. Its flight direction was to be controlled in azimuth from the launching plane but this stage of development was never achieved. There were about 100 constructed for test flights but none were completely successful. Gyro control was used for azimuth and glide angle (10 to 20 degrees). A variometer was used to control the glide at a fixed angle until the proper height above the surface was reached. Then the level was to be held constant by means of a Zeiss polarized light altimeter; however, this method of height control was never successful. Length 19-ft 8-inches; Span 8-ft 2-inches.

BV-246. - There were about 10 models of this glide bomb missile. No propulsion unit was used. It was designed by Dr.Vogt of Blohm and Voss, and was originally called - "Hagelkorn." All models of the BU-246 had a wing span of 14-ft 7-inches and length of 11-ft 1-inch. The early models were tested using gyro-stabilization, while some of the later models were radio controlled, as well as gyro-stabalized. All models were designed to be launched from launching aircraft and were fastened by bomb shackles. They were long range missiles, having a range of 100-miles when launched from 20,000-ft. This means a glide ratio of better than 25:1. There were a total of 400 of all models manufactured, these being used for test purposes. Because of political reasons, favor was shown to the V1, and production of the BV-246 was never started.

PEGER-X - Was a sub-sonic air-to-ground missile, manufactured by Rheinmetal-Borsig. The approximate speed was 280 meters per second. It was purely a glide bomb, no propulsion unit being used. It was radio or wire control. Range maximum 5000 meters. Length approximately 140-ft; span 47-ft 6-inches.

F - Unguided Missiles.

This class of missile is often associated with guided missiles, and some of their principles, especially their rocket propulsion units, are adaptations of guided missile work. The three missiles under this classification are all rocket propelled :

TIAFUN - Is covered under Technical Analysis Section of this report. It is a rocket propelled ground-to-ground, or ground-to-air missile. It was designed to replace normal artillery.

RHEINBOTE - Was a four-stage ground-to-ground rocket and was fired from a smooth bore barrel. Later it was used as only a three-stage missile with a length of 25-ft. The anticipated range was 150-km, but on trial firing a maximum of about 100-km was obtained.

R-100-BS - Was an air-to-air rocket assisted bomb.

G - Development of Missile Projects :

The following is a list of projects which were in some stage of development. Probably none were ever produced. No exact technical data is available for this report on these projects :

1 - Kurt - 1 and 2. Rocket motivated sea mine.
2 - MV - 1 Sub-sonic rocket propelled test missile.
3 - MF - 5 Surface-to-air sub-sonic missile. Dry fuel propulsion unit.
4 - Pirat - H Air-to-Ground missile.

5 - Hecht - Sub-sonic test missile.
6 - Rochen- Impulse wire controlled missile - rocket propelled.

7 - L 2)	Series of Unguided Glide Torpedoes
8 - L 10)	
9 - L 11)	
10 - L 30)	
11 - L 40)	
12 - L 50)	
13 - LT - 950)	

OUTLINE OF SECTION III.

III. TECHNICAL ANALYSIS OF GUIDED-MISSILE PROJECTS STUDIED BY CIOS TEAM 367.

2. TECHNICAL ANALYSIS OF MISSILE PROJECTS.

A. Henschel Guided Missile Series HS-293 to HS-298 including HS-117 Schmetterling.

B. Wasserfall.

C. Enzian.

D. Komet 2.

E. Tiafun (Unguided)

3. TECHNICAL ANALYSIS OF HOMING DEVICES.

A. Madrid.

B. Derna.

C. Television Homing.

D. Homing Device developed by Dr. Rambowska.

E. Messinagerät.

4. RESEARCH RELATED TO GUIDED MISSILE WORK.

A. General Information.

B. Report on the Interrogation of Dr. Kasper of A.E.G.

C. Report on the Interrogation of Dr. Rudat of A.E.G.

D. Radio Control of V-2.

E. Controlling of the Fusing of the HS-293 by means of Radar (Translation).

2. Technical Analysis of Missile Projects.

A. Heschel Guided Missile Series HS 293 to HS 298 including HS-117 - Schmetterling.

While investigating the Guided Missile target at Woffleben, a chart was located which gives the names and sections of the research staff of Dr. Wagner, working on Henschel Guided Missile projects. Woffleben was the chief evacuation centre for the Henschel plant working on Schmetterling interrogation revealed that two men, Dr. Marcard and Dipl. Eng. Henrici were in the vicinity and available for interrogation. Dr. Marcard was head of the electrical and electronics section for Guided Missile work, and had been with Dr. Wagner for several years. Dipl. Eng. Henrici was head of the mechanical construction section for Schmetterling.

Both men were asked to write as complete a story as possible of their activities with Henschel development. Both speak and write English so their reports were in English; however, slight re-editing was necessary for this report.

The following is a comprehensive story of the work of Dr. Marcard written by himself.

Report by Dr. Eduard Marcard, Chief-Electrical-Engineer of Abteilung F. Henschel Flugzeug-Werke A.G. Berlin-Schönefeld. (later Oder A.G. Nordhausen/Harz).

On April 1st 1941 I was engaged by Prof, Wagner as a leading engineer for electric development. Prof. Wagner had since 1940 been working with Dipl. Ing. Schwarzmann at the HS 293, and after Herr Schwarzmann left Prof. Wagner in January 1942 in order to start a factory of his own, (Donag) at Vienna, for developing and manufacturing parts for Prof. Wagners models, I was made chief-electrical-engineer in Prof. Wagners' department.

During the following four years I had the responsibility for carrying out all of Prof. Wagner's ideas regarding the electric equipment. It is impossible to recollect in a few weeks the details of all the work that was done and the experience that was gained in a long period of hard work, comprising a remarkably large scope. No earlier experience existing, most of the problems had to be solved by us alone and nearly everything had to be especially designed for the purpose.

This report is somewhat difficult as it is nearly all written from memory, since I personally possess no records except a few notes. Amongst my two nearest and confidential fellow-workers, Herr Mühlbacher and Herr Ing. Diederich, only the latter - living now at Göttingen - was within reach and able to help me, while Dr. Mühlbacher is supposed to be in Vienna.

In the following I shall try my best to outline what work was done by the electrical development section on the remote controls and equipment for nearly thirty different models of gliders designed by Prof. Wagner. If requested, of course, a more exact and detailed report could be issued, if the necessary time were granted. This is possible since all circuits, developments, experiments and tests regarding electrical matters, including all plans for the production, testing apparatus, etc., were completed under my supervision.

List of Types.

Before going into detail, I present a list of all types that were designed and a brief explanation of each one. The more outstanding models are more fully described later. All types are more or less modifications of the standard-model HS 293, which was the first and only one actually built in large numbers.

HS 293 V2. First experiemental models 1940/41. Glider without rocket motor. Standard control system employing potentiometers. Lateral control by flaps, elevator control by engine unit. No rudder. Receiver Strassburg E 30. Filter and DC-Amplifier. (Aufschaltgerät Strassburg) Power supply by batteries for 24 and 210 volts. Current approx. 30 Amp. Number of valves: 27. Highfrequency: "Kehl" - frequency (Approx. 6 m band) Control-frequencies: 1000, 1500, 8000, 12000 cycl./sec. Control-stick-contact-frequency: 10 cycl./sec.

HS 293 V3. Improved experimental model 1941. Rocket motor attached. Wiring and separate apparatus combined in unit. (SAG) 24 volt-supply by accumulator. 210 volts converter. Production begun.

HS 293 Ac. Production model 1942. Improved 293 V3. Later equipped with relays instead of DC-Amplifier. Electric damping system by relays. Supplementary equipment for remote control by wire was available.

HS 293 A1. Improved production model 1943. Receiver Strassburg E 230 with relays in output stage. DC-relays-amplifier ASG 230 Universal connecting unit SAG 230. Number of valves reduced to 12. Total amount of 293 V2 - A1 built is approx. 12,000.

HS 293 A2. Latest production model 1944. New simplified control system. Control-stick-contact-frequency, lateral: 16 cycl, elevator: 5 cycl. Lateral control: new 16 cycl. filter and new potentiometer (6500 Ohms), Wagner-flaps. For elevator control Wagner-flaps were used which were operated by magnets energized directly from the receiver relays. DC-gyro. Forerunner of 298/117 controlling system. Ready for production, but stopped by air ministry.

HS 293 B. This designation does not refer to a special glider model, but indicates employment of a wire control system which was started in 1941. Upon completion of this development, all models HS 293 to HS 296 could be controlled by either radio or wire. For this purpose the receiver E 230 had to be changed for the receiver E 237 (Duisburg) and in the carrier plane the transmitter FuG 203 or 206 had to be replaced by the transmitter FuG 207 (Dortmund). Also two coils had to be attached to the glider and two more to the carrier-plane. Built as supplementary equipment.

HS 293 C1-3. Glider was small edition of HS 294. Production only in small quantity for experimental work and for testing new control systems in 1942/43 such as the system 293 E, 293 A2, etc.

HS 293 D. Experimental type. Glider like 293 but with television equipment. A small number was produced, trials being carried out in conjunction with Forschungsanstalt der Reichspost and Fernseh A.G. Berlin 1942-44. Result: Prof. Wagner preferred "Fevi."

HS 293 E. Model for a new remote control system based on a turn-coil instead of potentiometers. Development started in 1942. Trials with glider 293 C. Plan then given up in 1943 in favor of a new potentiometer control system.

HS 293 F. Design of a tail-less glider. Modified controls of 293 A Not built.

HS 293 G. Experimental type. Glider and control system similar to 293, but capable of vertical as well as horizontal flight path, thus possessing the characteristics of HS 293 and of the "Fritz X" (Dr. Kramer). For this purpose a special gyro was constructed, which could be tilted over 90 degrees from vertical to lateral axis. Ten models built in 1942, then work stopped by air ministry in favor of "Fritz X."

HS 293 H. Glider 293 A1 for use as anti-aircraft weapon. Special radio equipment used for remote control of fuse by means of 5th control-channel. Standard type 293 A1 could be converted to a 293 H by exchanging receiver E 230 with E 230 H/I and by attaching a special relay-box. Small quantity built in 1943/44 by conversion and use of supplementary equipment.

HS 293 I. Like 293 H but different amount of explosives. Only planned 1943.

HS 294 A. Special model combining glider with torpedo. Controls like 293 A1 but special fuse devices for blowing off fuselage rear section and wings as soon as body touches water surface, fuselage front section then cruising as torpedo under water. Small quantity built for experimental purposes 1941-43. (Largest type designed by Prof. Wagner).

HS 294 H. Like 294 A but equipped with AEG-controlling system. Only planned 1942.

HS 295
HS 296 Modifications of 293 A with the same electric equipment. Only difference, fuselage front section and amount of explosives. Small quantity built 1942/43.

HS 297. Special model. Anti-aircraft weapon for fighting planes from the ground. First planned in 1941 but rejected by air ministry as being a defence weapon. In 1943, urgently requested and therefore replanned on large scale with the designation 8-117.

HS 298. Special model. Anti-aircraft weapon carried by fighters or bombers. First planned in 1941 but rejected by air ministry, only work on receiver E 232 (Colmar) being carried on. In 1943 urgently requested and therefore replanned on large scale production basis. New controlling system similar to 293 A2 but simplified. Power supply by generator with airscrew. Additional electric distance-meter for special fuse. Experimental series since 1944, mass-production ready. Smallest type designed by Prof. Wagner. (Competitor to Dr. Kramers' "X4")

8 - 117. ("Schmetterling") Continuation of design HS 297. Special model launched from the ground for fighting aircraft. Controlling system and electric equipment like HS 298 but affording several additional facilities such as igniting system for launching-rockets, speed-regulator, special control-motor for gyro, etc. Experimental models begun in 1944. Serial production planned for 1945 on large scale as "Führer-Notprogramm" (Competitors: Wasserfall, Rheintochter and Enzian; but 8-117 was the simplest design requiring the smallest amount of energy.

8 - 117C. Development of 8-117 in autumn 1944. Equipped with receiver E 232 (Colmar) and distance-meter "Kakadu" or "Fox."

8 - 117 A1 (A2) Production model. Latest model of 8-117 in March 1945. Type ready for production. New developments: Receiver for 6 m - band or decimeter-band (E 232 a/b Colmar or Strassburg E 230/3 or Brigg E 531, Distance-Meter: Kakadu, Marabu, Fox or Meise. Pilot-transmitter "Ruse" for radiolocation. Automatic detonation when control-system fails. (Additional homing-apparatus planned).

8-117 H. Modification of 8-117 to be carried by planes as anti-aircraft weapon. Improvement of the 293 H idea with the advantage that the 8-117 H possesses a rate of climb. Controlling system and electric equipment resembling 298.

Late experimental types :

HS 293 V4. Experimental model 1943/44 based on 293 A but elevator engine replaced by magnets and Wagner-flaps.

HS 293 V5. Exp. model 1944 resembling 293 A but containing alterations for use by jet-propelled carrier-planes: Electrical features like 293 A2.

HS 293 V6. Exp. model 1944 like 293 V5 but with electric controlling system of 298.

HS 293 V8. Exp. model 1944 like 293 A1 but equipped with receiver E 531 (Brigg) for testing the decimeter system "Kogge."

This list does not completely cover all experimental and production types, but it contains all the outstanding models which are of any interest because of their controlling system and electric equipment.

The Controlling System.

Although the principles of the remote-controlling-system, which Prof. Wagner used for his gliders are generally known, and are described in detail in the volume "Steuerung" of the "Gerätehandbuch für HS 293 A1" which was written under my supervision and edited in September 44, I shall briefly touch this subject.

The fundamental ideas of the controlling system were never changed, only modified to meet the special needs of the different models of gliders. Besides that, with growing experience, improvements were achieved bringing greater simplicity to the system.

For the transfer of the control signals for the two lateral and two elevator controls, four low-frequency channels (1000, 1500, 8000 and 12000 cycl/sec) were provided. These low-frequencies were generated by four oscillator-circuits in the modulator unit. By means of the control-stick-transmitter these low-frequencies are switched in a 10 cycl/sec-rhythm (or in later system 16 and 5 cycl/sec). This is done by two change-over-switches which alternately open or close the two complementary frequencies for the lateral resp. elevator control. (1000 and 1500 cycl/sec and 8000 and 12000 cycl/sec). Thus when one complementary frequency is switched on, the other one is off and vice-versa, this occurring at the "column-stick-switch-frequency" (Knüppel" - or "Tast-Frequenz") of 10 cycl/sec. The variation of the control signal is achieved by altering the switching-time-ratio. For this purpose the key-pin, which mechanically operates the control-switch by touching the curved surface of a rotating cylinder bearing a special cam, is moved in a direction parallel to the cylinder axis. The ratio of the difference of the switching times of the one modulation a and the other one called b to the time of one revolution of the cam-cylinder (a plus b equaling one period) is the control signal ratio $K = \frac{a-b}{a+b}$, which can figure from -1 over 0 to + 1.

Thus the modulation frequencies are hetrodyned by the switching-frequency, which is a mean curve with varying spaces owing to the imposed time ratios. The wireless transmitter is then modulated by these four low-frequencies.

In the receiver these modulation-frequencies are, after demodulation, selected and rectified, and so combined that the two complementary currents operate one output relays. In a following filter-circuit the currents are smoothed, the direct current mean value being led then to the double-potentiometers. In case the control signal ratio differs from nil, then an EMF will appear across the taps of the potentiometers, the electric balance being disturbed. This EMF energizes the control windings of the attached relay, which begins to operate, thus also energizing the magnets for the control-units.

In order to attain a damping of the circular-acceleration and therefore to achieve a quick reaction, a special damping circuit is provided. This circuit also has great influence on the rigidity (Steilfigkeit) of the control. The outlay of the circuit and the dimensions of its elements were therefore of importance and had to be carefully chosen, the finished system being exactly tested on a corresponding model in the wind tunnel. These tests were one of our principal tasks when a new controlling system had been developed or the standard controls had to be adjusted to a new type of glider. In general, it can be stated that if a control system had been brought to satisfaction in the wind tunnel, then it was sure to function in the expected manner in operation.

During recent years many damping circuits have been developed and examined, the simplest being the latest one used in the lateral controlling system of the 298 and 8-117. Here a tension-counter-coupling is employed, which by means of a C-R-circuit ensures the proper phase angle between currents in the control winding and the damping winding of the relays.

On the lateral controls the magnets, once operating in consequence of an EMF appearing across the taps of the potentiometers, will turn the plane until the commanded angle is reached. In this case, by means of the mechanical coupling between the gyro and the potentiometer taps, a Feed-back (Rückführung) is obtained and the plane rolls until the electric balance in the potentiometer circuit is restored and the EMF across the taps becomes nil.

But this method is not necessary for the elevator control. Here, as done in the latest models, the elevator magnets may be energized directly from the receiver output relays. By Prof. Wagner's controlling system on the lateral component, the angle between lateral axis and horizon was controlled (or more exactly between lateral axis and gyro-axis); and on the elevator component, the angle of a flap (, by means of the time mean value) is controlled.

The flaps of the lateral control (and regarding the latest controlling system with Wagner-flaps, also the elevator control flaps) are oscillating when the control signal ratio is nil. This was attained in the old system by means of a filter leaving a certain AC-tension to pass. Later, this effect was obtained by using a self-generating circuit for the lateral control feeding the damping windings of the relays with a triangular tension. This oscillating of the flaps ensured greatest sensitiveness with smallest time delay. As soon as the signal ratio differs from nil the time of rest in the extremes of the flaps changes according to the commanded ratio. Only after a certain ratio is exceeded do the flaps rest in the extreme position. This certain ratio known as the flapping-range("Klapperbereich") figures to about ± 35 degrees and is also a measure for the sufficiency of the damping and rigidity of the control circuit.

In order to obtain an exact elevator control at increasing speed, a special device was designed. This consisted of a drag plate for measuring the dynamic pressure and varying the control range of the flaps with respect to speed. This was obtained with the old elevator control operated by potentiometers by gradually limiting the active section of the latter. For the Wagner flaps another system was chosen which mechanically limited the stroke of the magnets. Later for the 8-117, a new type of apparatus was developed which regulated the cruising speed itself.

The general transmitting method for the controls was by wireless. But in order to avoid interference by enemy radio signals, a remote control by means of a wire connection could be used. (HS 293 B). At last also a decimeter wireless system could be used, but as all these systems only related to the transmitting method having no reactions on the actual controlling system, they are described later.

The Electric Equipment of the Standard Type HS 293.

The controlling devices for the HS 293 were placed in the fuselage rear section, most of them on the exchangeable apparatus board. The elevator unit was attached to the rear below the horizontal tail surfaces, while the lateral flaps operated by magnets were fixed on the wings.

On the left side of the vertically positioned apparatus board the receiver, the filter and amplifier, and the DC-converter were mounted. The right side bore the gyro and potentiometer unit, the connecting apparatus, the accumulator, the gyro-converter and the cable adapter. The aerial transformer and the "pull-off-plug," by which the controls were energized as long as the glider was attached to the carrier-plane, were fastened to the skin of the fuselage rear section.

A more detailed description of the main parts follows:

1) Receiver "Strassburg" E 30 and E 230.

Manufactured by Strassfurter Rundfunk GmbH Strassfurt. Designed by Obering. Theo Sturm, Strassfurt, originally for the "Fritx X" of Dr. Kramer, but being a highly efficient apparatus for remote controlled bombs, also used in all models of Prof. Wagner except in the HS 298 and 8-117.

The receiver E 30 was a 15 valve superheterodyne set including four power valves in the output stages for the four controls. AVC and AFC were installed, the sensitiveness approximated 10 uV. The wave range was adjustable to 18 fixed channels lying in the 6m-band. Owing to our alterations on the filter and amplifier unit (Aufschaltgerät) and replacing of valves by relays, the Strassburg-receiver was altered in 1943. The four output valves were exchanged with two Siemens T-relays, this new 12 valve set being called E 230. Its sensibility was raised to approx. 2 uV. At our request the apparatus was equipped with an output adapter switch (A,B,C) enabling the set to be combined with different following circuits. (With switch on "A" both controls were energized by 210 volts; switch on "B" connected the elevator control to 24 volts while the lateral control remained on 210 volts switch position "C" meant that both controls were on 24 volts). Thus the serial production of the receiver did not have to be disturbed while we had more freedom for our development of controls. The other principal features of the set remained unaltered.

By order of the air ministry the receiver was built in several editions (E 230/1, E 230/2, etc), operating on different wave bands.

An aerial transformer was attached to the receiver through a screened cable and numerous types of these (AGE) were necessary for attaining the correct adaptment to the various kinds of aerials needed by the different types of gliders. Generally we chose two types of aerials, the one connecting the transformer directly with the trailing edge of a wing, while the other was insulately mounted near the horizontal tail surfaces. In order to receive a better aerial characteristic the use of a special kind of dipol using the trailing edge of the wings as reflectors was planned but later on dropped when the decimeter-system was started.

Great aerial difficulties also arose at the beginning when the first rocket motor was attached, as interferences were caused by electrons ejected from the jet. But after exact examinations this disturbance could be eliminated by carefully locating the aerial and taking special screening measures.

2) Filter and Amplifier Unit. (Aufschaltgerät ASG 30 and ASG 230).

Manufactured by Opta Radio AG Leipzig resp. Loewe Radio AG formerly known as Leipziger Funkgerätebau Gesellschaft (LFG). Originally designed by Dipl. Ing. Schwarzmann in collaboration with LFG as "Aufschaltgerät Strassburg" for the HS 293 V2 being a four-channel filter- and DC-amplifier-unit. This apparatus, built later as ASG 30, contained 12 valves requiring a DC supply of 24 and 210 volts and a AC supply of 36 volts with a frequency of 500 cycl/sec.

Two complementary channels were combined symetrically to one section, one being for the lateral, the other for the elevator control components. Both resembled each other in their outlay. Each filter section contained two symetrical branches of capacitances and inductances forming a low pass for 10 cycl/sec. By this the DC-mean value was composed leaving a certain small AC rest tension for energizing the controls at control ratio nil. Each branch of the lateral section was terminated to adapt the following potentiometer resistance of 1700 ohms, for the elevator control this value being 17000 ohms. The amplifier of each section comprised also two symetrical branches for the amplification of the two complementary direct currents. This occurred in three stages, the second stage performing as a modulator operating with 500 cycl/sec. The output stages of each section, containing two power valves each, energized the output circuits. These were two interstage vacuum relays for operating the lateral control magnets and the midtapped field windings of the elevator motor.

This apparatus also contained the circuit for the damping of the lateral controls. This was composed of an R-C circuit switched by means of special contacts fixed to the control rods of the flaps, thereby ensuring the appearance of the damping tension in the proper phase angle with respect to the controlling tension. The damping tension which charged the R-C circuit being in this case provided by a special 4 volt battery.

Because of valve troubles in this apparatus, by which more than 50% of the production became defective,(thus endangering the military use of the glider) this unit had to be entirely altered. Prof. Wagner told me in the summer of 1942 to make a new design for this apparatus and to try to reduce the number of valves. A few weeks later, after satisfying windtunnel experiments, I could present a new unit which, after having been tested on trial flights, was ready for manufacture in autumn of that year. This apparatus contained no valves at all. For the lateral and elevator control only one relay for each had been inserted, providing an additional third relay for the switching of the damping circuit indtead of the unreliable contacts on the control rods of the flaps. For the present, the filter sections remained unchanged. This new design was only possible in this simple manner by making use of the new Siemens-T-relays, having a sensitiveness of approx. 2 μW and a time delay of approx. 1 m-sec. But the original Siemens-T-relays did not at once serve the purpose. Only after making troublesome trials to adjust it to a higher degree of sensitiveness (approx. 1 μW) in our own laboratories and after carefully examining the stability thereof could it be chosen for the purpose. After we had built the first series ourselves the Loewe Radio AG then took over the manufacture of this apparatus with the designation ASG 230 whilst Siemens provided the necessary relays. But for a long time the relays still had to be adjusted in our laboratories as nobody else was prepared to bear the responsibility for this work. Only after several months was Siemens willing to manufacture these relays with this extreme adjustment. Later this relay became the most required one in the Siemens program. (Type T-relays 55 k).

3) Converter DC-DC.

Type GGU. Input 24 volts, 4 amp DC, output 210 volts, approx. 300-m-amp DC. Manufactured by Oemig, Hartha i.Saxony. Served for supplying the high tension for the anodes of the receiver valves, the field windings of the elevator motor, etc.

4) Gyroscope and Potentiometer Unit.

In the models HS 293, including the HS 293 A1, the gyro HV3 manufactured by Horn at Leipzig was made use of; it was energized by rotary current of 36 volts with a frequency of 500 cycl/sec, reaching approx. 30,000 revolutions/min. The gyro was mounted in our factory on a special stand allowing the double-potentiometers to be coupled by means of a flexible coupling.

This double-potentiometer had been especially designed for the HS 293 by the Askania-Werke AG at Berlin and was manufactured there also. (Later this firm started a branch manufacture in Denmark, Danavox, Kopenhagen). The two combined potentiometers (type LPT) had a resistance of 1700 ohms each. It had been a hard job for the firm to design a potentiometer meeting our conditions not only regarding the electric values, but also with respect to the mechanical ones, as the torsion resistance had to be extremely low. This was approx. 2 cmg. This had been achieved by using special contacts for the taps, so called "flylegs" (Fliegenbein-Kontakte).

The gyro-potentiometer combination was one of the most important devices for the lateral control as it provided a relative stable system for it. In order to do so, the gyro axis was fixed until the glider was dropped from the carrier-plane and, at this moment, the gyro axis was automatically released by a special device attached to the gyro unit.

5) Connecting Apparatus. (Sammelgerät SAG 30 and SAG 230).

Manufactured by Telefonbau & Normalzeit, (T & N), Frankfurt/Main, Berlin and Forst (Niederlausitz) and by Donauländische, Apparatebau Gesellschaft (Donag), Vienna. The device was introduced in 1942 following a previous model. While in the first 293 model, the V2, the wiring connecting the different apparatus had been attached to the apparatus board, this model contained all necessary wiring systems including a number of smaller units, which were before spread all over the apparatus board. The connecting apparatus was bonded to the different main devices by means of combined cables and plugs, thus enabling an easy exchange. The main contents were: the main supply switch, the filter circuit for smoothing the 210 voltage DC, the two Birka-interstage-vacuum-relays for the lateral controls (having spark suppression and anti-distrubance circuits attached), the resistance for the armature of the elevator motor, the potentiometers across the input circuits of the filter sections in the ASG-apparatus for compensating the inaccuracy of the electric parts and insuring the exactness of the controls, the delaying-relays and adjustable resistance by which the armature of the elevator motor and the ignition of the rocket motor were energized, the testing contact plate and the transmitter for the remote controlled temperature-meter. This apparatus was built in various different types, for nearly every special outfit or alteration had reactions on this unit. The most important type was the SAG 30 built for the HS 293 models. It was later succeeded by the SAG 230, a universal model which could also meet the special requirements of the HS 294.

6) Power Plant.

25 volt Edison steel accumulator; type 25 NCL 10. Capacity 10 amp.hours. Manufactured by Deutsche Edison Akkumulatoren Company, Berlin, Hannover and Hagen i.W. (Deac).

After the first experimental gliders (293 V2) had been equipped with a battery (Rulag-Block) to provide the low and high tension and this system was a failure, an accumulator was installed, and the high tension was produced by an accessory converter. The Deac-accumulator served the purpose quite well, especially regarding the extremely high currents required by the old control system (reaching 35 amp and in case of HS 294 approx. 40 amp). Owing to the loss of voltage in consequence of the high currents in the lead-in-wires, a 25 volt model had been chosen.

7) Converter DC-AC.

Type GDU. Input 24 volts, 5 amp DC, output 36 volts rotatory current 500 cycl/sec. Flywheel-brake for stabilizing the frequency. Manufactured by Oemig, Hartha i. Saxony (later also by Kiesewetter, Stuttgart). Served for energizing the gyro motor, and in case of ASG 30 being installed in the modulator.

8) Cable Adaptor.

Accessory to the receiver E 237 (Duisburg) for the remote control system by wire and could be installed on a specially provided place on the apparatus board. The cable adapter LGE consisted of a transformer in a screened box for adapting the characteristic impedance of the two conducting wires connecting the glider with the carrier plane, to the input circuit of the receiver. (More details: HS 293 B)

9) Elevator Control Unit. (Hohenrudermaschine HRM)

Designed by Dipl.Ing.Schwarzmann for the HS 293 in 1940, manufactured by List, Berlin-Teltow, Donag, Vienna and several other smaller firms. This apparatus consisted of the reversable motor for moving the elevator control flap, the double-potentiometer for the elevator control circuit (the taps of which were mechanically controlled by the motor in order to receive a feed back (Rückführung), the generator for supplying the tension for the damping circuit of this control being also driven by the motor, and the drag-meter device controlling accessory taps of the double-potentiometers for limiting the active sections thereof. The working system of this control unit was very similar to that of the lateral control.

10) Flap Magnets.

The magnets controlling the flaps of the lateral control mounted in each wing of the glider HS 293 were of the one-stroke type containing a returning spring. The required energy amounted to 360 watts. Manufacturers: List, Berlin-Teltow.

11) Pull-off-plug. (Abreiss-Stecker)

Manufactured by Jatow, Magdeburg. By this 14-poled plug the electric connection - for supplying the cathodes of the valves, supervising their function, etc - between the carrier plane and the glider was maintained up to the moment when the glider was dropped. This plug also contained several change-over-switches, which were automatically operated as soon as the plug was pulled, thereby connecting the whole electric equipment of the glider to its own power plant. Also two gliding-contacts were provided for igniting the flares fixed to the rear of the glider as soon as it had been launched.

12) Rocket Motor.

Manufactured for type HS 293 by Walther at Kiel and others. Unit was attached below the fuselage of the glider. Regarding the electric outfit, it was connected by a plug in the fuselage to the connecting apparatus, thereby being ignited. An electric fuse in series with the igniting system prevented short-circuiting of the power plant after the rocket motor had been started, as the heat of the jet then generally welded the igniting system thereby forming a short-circuit.

13) Flares and Lamps.

In order to navigate the glider from the carrier plane, several flares for day-attack were mounted to the rear of the glider. During dawn a small electric search light situated next to the flares served the same purpose.

14) Fuse.

The fuse for detonating the explosives in the fuselage front section was a normal type used by the Luftwaffe containing an electric safety circuit operated by an acceleration switch.

Testing Apparatus.

In order to check the manufactured parts for the HS 293 and for testing the whole electric control system before use at the front for nearly every unit a special electric checking apparatus had to be developed by us. But owing to the great variety required and the complicated functions it is not possible to describe this interesting apparatus here now.

Carrier Plane Equipment.

The carrier planes for the HS 293 and modifications (generally He 111, Do 217, etc) had to be installed with special equipment for the release and remote control of the gliders. This outfit was planned by the Versuchsanstalt der Luftwaffe at Peenemünde in collaboration with us while the actual installation was generally carried out by aeroplane factories under the supervision of Telefunken GmbH, Berlin. The electric equipment for the remote control consisted of: the control-stick-transmitter, the switch-box, the modulator, the transmitter, the aerial-transformer and aerial. The different apparatus were combined into various equipment serving several purposes, e.g. for the release and remote control of one or several HS-gliders or for the release and remote control of HS-gliders and "Fritz X" - bombs by the same carrier plane. Also for the remote control system by wire, special equipment had been provided. The principal apparatus belonging to this equipment may now be described briefly :

1) Control Stick Transmitter. (Kommando-Geber-Gerät)

This device, having the task of transforming the positions of the control stick constantly and without time delay into electric signals, has already been referred to in the chapter - "The controlling system" The apparatus was constructed especially for the HS 293 in 1940 by Prof. Wagner and Ing. Hell, a member of our staff, and was manufactured for many years without alteration being necessary. It was actually the only control stick transmitter of which practical use was made of in controlling Prof. Wagner's gliders.

Corresponding to the controlling methods based on polar coordinates, two components had to be transferred. In this apparatus the movements of the control stick were mechanically analysed to the two components, a rotary and inclining motion, each of them controlling the movement of a key pin, touching the surface of a rotating cylinder, in a direction parallel to the axis thereof. By means of the key pin a switching device was operated, by which the complementary low frequencies were alternatively switched on and off. The surfaces of both cylinders bore a cam, the elevated areas of which having the shape similar to a triangle, while the remaining surfaces possessed the same form in reverse. Thus each cylinder surface was divided into two equal triangular areas, one being elevated regarding the other, thereby forming a cam. If the key pin was positioned in the middle of the cylindrical surface, then the switching device would switch on the one frequency as long as the other was off and vice versa. But when the key pin was brought to a position other than nil (as just described), the switching ratio and therewith also the signal ratio would have another value corresponding to the actual control stick position. These control stick transmitters were first layed out for a switching frequency of 10 cycl/sec for both components and a maximum signal ratio of 0.8, but for experimental purposes and especially for the control system used later these figures were changed. The new controlling system afforded a switching frequency of 5 resp. 16 cycl/sec, while the signal ratio after employing the Wagner-flaps was raised to 0.95. Although this control stick transmitter had been working to satisfaction, Prof.Wagner was early interested to improve this device, as the exactness of the controls and of the hitting of the target depended on it to a large extent.

The first improvement, more experimentally, was an accessory electric device (built by Friesecke & Höpfner, Berlin-Babelsberg), by which an additional voltage, being the differential coefficient of the actual control voltage, was superimposed on the latter. This unit therefore worked on the same principles as the described damping circuits for the controls. By means of this apparatus Prof. Wagner had hoped to obtain an easier and more exact control by inexperienced bomb aimers, but real success was not achieved.

The other improvements related entirely to the construction of the transmitter itself. During the last years constructions were made, an interesting one being the "Knirps" by Opta Radio AG, originally designed for the control of the "Fritz X" and containing instead of rotating cammed cylinders, an adjustable differential-gear by which the switches were operated.

The most important new design was that by Obering.Sturm, Stassfurter Rundfunk Gesellschaft, Stassfurt and Alexisbad. This transmitter, equally useful for cartesian and polar coordinates worked mainly on electric principals, generating the frequencies by sawtooth-oscillators, wherein the signal ratio was adjusted by electric means. This system was used for many years for checking the Strassburg receivers. Ing.Krüger, belonging to our own staff, added to this transmitter a new control stick device, which by mechanical means allowed movements of the control column corresponding to the cartesian coordinate system (this being easier for the bomb aimer), whilst the electric signal output answered either to polar coordinates (for HS-gliders, like 298 and 8-117) or to cartesian coordinates (for alien constructions). This apparatus was accomplished at the beginning of 1945 and was going to be manufactured for the 8 - 117 equipment by Askania-Werke, Berlin. The designations were: "Pol," "Karte," "Klapper," etc.

2) Switch Box.

This device contained the necessary switches for energizing the whole equipment, for selecting the glider to be dropped next and for igniting the flares or setting the rear search light in action. Also the control instruments for the control stick, the high frequency, and the temperature in the glider were placed here.

3) Modulator.

This apparatus for generating the four low frequencies referred to earlier contained four separate oscillator circuits, which were switched by the control stick transmitter. The complementary signals being then amplified in a separate stage before being conducted to the transmitter. By means of four potentiometers the amplitudes of each frequency could be adjusted. The modulator was energized by 24 and 210 volts DC.

4) Transmitter. (FuG 203 and 206. "Kehl")

The wireless transmitter FuG 203 was designed and manufactured by Telefunken GmbH Berlin. It was an quartz-controlled ultra-short-wave transmitter comprising three stages and of normal design. By changing the quartz-crystal (marked K1 to K18) 18 different frequencies on the 6 m band could be chosen. The energy supply came from a special converter.

This transmitter was used for many years and later replaced by a new one, the FuG 206, working on the same principles. Attached to the transmitter was the aerial transformer and the aerial fixed to the carrier plane. A special delay switch diminished the aerial output during the launching of the glider in order to prevent an over control of the receiver. For use of the remote control system working by wire the modulator and transmitter had to be exchanged. For details see chapter referring to the HS 293 B.

An interesting accessory to the carrier plane equipment was the "distance sight vane" (Fernvisier "Fevi") which Prof. Wagner had planned and at which Ing. Hell had been working for several years. The control of the HS-gliders by the bomb aimer was obtained merely by direct sight, the use of a telescope being impossible in the plane in consequence of the perpetually occurring accelerations. Therefore the tactical control range was limited by eye sight. For achieving a larger range either the installment of a television-eye (HS 293 D) or the use of a stabilized telescope (Fevi) was necessary. Prof. Wagner tried both but believed the latter to be the one.

Many kinds of gyro-stabilized telescopes were constructed, and attempts had been made to stabilize the head of the bomb aimer with the telescope attached to it, but perfection had not been attained allowing practical use. In 1944 this problem was solved, but too late to become official carrier plane equipment. Later this achievement could be made use of in connection with the control of the 8 - 117 so far as this was done by eye-sight. For the training of the bomb aimers and for the checking of the charged carrier planes by airport personnel, much interesting special apparatus had been developed by our staff and manufactured by different firms during the past years. But to go into detail in these matters would lead too far.

<u>The Development and Special Equipment for the Remote Control by Wire. (HS 293 B)</u>.

To avoid interference by enemy radio signals a remote control system by means of a wire connection was already planned in 1940. The solution of the mechanical task of laying cables at high speed in the air was taken over by Prof. Wagner and Dipl. Ing. Lahde, a member of his staff. Work upon another competing system had been started at the same time by Dr. Kramer (Deutsche Versuchsanstalt für Luftfahrt at Berlin). At last in 1943, after nearly endless trials, both rival experiences could be combined and a wire coil system, ready for manufacture, was obtained.

The electrical development in this case was not so easy as it first seemed to be, as the conductance of the wire was limited for mechanical reasons. These demanded the use of a wire of steel having a diameter of 0.2 mm and a non-reactive resistance of approx. 5 ohms/m. Further difficulties arose by the high inductance and capacity of the produced coils of the lines. Another problem was the choice of the control system and the number of employed wires.

In 1941 Obering. Sturm and myself took up this work and after a few months of collaboration between our firms we could produce a wire control system designated later Dortmund-Duisburg.

As this set had to be exchanged in the most simple manner with the wireless apparatus, the standard remote control system had to be maintained by transferring the four control frequencies without a carrier. But due to the great attenuation of the cable system these frequencies had to be reduced to approx. 500 cycl/sec for the one complementary signal component and to approx. 700 cycl/sec for the other. For the conduction an insulated double line was found best and as the mechanical system afforded one coil at each end of one wire this meant altogether four coils, two attached to the gliders wings edges and two fixed to the carrier plane beneath the fuselage. The inductance of the coils was eliminated by short-circuiting the layers thereof in a special manner.

The line consisting of the two wires could be let out up to a total length of 30 km, thereby obtaining a tactical remote control range of approx. 20 km in consequence of the two differing flying paths. As the resistance of the wire system was 10 kilo-ohms/km, a total resistance of 300 kilo-ohms was obtained as maximum.

The capacitance of the line floating in the air was in case of HS 293-models approx. 2,000 pF/m, the leakage and inductance being neglectable. The characteristic impedance equaled about 40 Kilo-ohms. The attenuation of the line was for the 500 cycl/sec-band 0.15 Neper/km and for the 700 cycl/sec-band 0.17 Neper/km.

To these and other data regarding the line, various investigations had to be made before the apparatus system could be finally layed out. These trials being made during flights and on lines carried by kite-balloons.

For control by wire the following new apparatus were required on the transmitting side: The low frequency oscillator (instead of the modulator), the amplifier (instead of the wireless transmitter), the cable-adapter and the wire coils. In case several gliders were to be launched, a distributing switch had to be installed also.

1) <u>The Low Frequency Oscillator</u>. (Summer Dortmund FuG 207)

Manufactured by Stassfurter Rundfunk Gesellschaft. This unit generated the four low frequencies for the control system. These were: 475 and 525 cycl/sec for the one control component, 665 and 735 cycl/sec for the other one. For the lateral and elevator control each, one oscillator circuit was provided, operating on 500 cycl/sec and 700 cycl/sec. These two circuits were detuned to an extent of ± 5% by switching coupled circuits comprising a reactance. Thus, the change over from the one complementary frequency to the other occurred without phase-leap. This was an improvement over the old modulator apparatus belonging to the wireless equipment FuG 203, in which the four separate oscillators were switched directly by opening and closing the anode circuits of the oscillator valves, thereby causing a phase-leap between to complementary frequencies, which resulted in disturbances (Unruhe) of the control system.

2) The Amplifier. (Verstärker Dortmund FuG 207)

Manufactured by Stassturter Rundfunk Gesellschaft. This apparatus, like the oscillator, were built in a manner allowing them to be easily exchanged with the corresponding wireless units, boxes and plugs therefore being the same. The four control frequencies were amplified in this device to an output voltage of approx. 35 volts and then lead to the cable adapter.

3) Cable Adapter. (LGS Dortmund FuG 207)

By means of this transformer the control frequencies were transformed to an output tension of 800 volts and then lead to the coils. In the glider the following manipulations had to take place for the establishment of remote control by wire: Exchange of the receiver, proof if cable adapter was at its place or installment thereof, mounting of the coils to the predetermined fittings and plugs.

Receiver E.237. Duisburg.

Manufactured by Stassturter Rundfunk Ges. Four valve low frequency amplifier built for the special purpose of substituting the wireless receiver Strassburg (E.30 or E.230) when wireless control was to be replaced by cable control. Working frequencies corresponding to oscillator already referred to : Input sensitiveness: 20 m volts, AVC installed, output circuits similar to E 230, by means of relays. (Therefore no reactions on the following control apparatus). Amplification and AVC allowing a control range up to 35 km. Box and plugging etc., like E.230.

The Wire Coils.

The mechancial construction of the coils and the details thereof are not within the scope of this report. The coils attached to the carrier plane contained each 12.000 m, while the coils fixed to the glider bore 18.000 m each. This difference of length was necessary with respect to the higher cruising speed of the glider in order to prevent any additional strain of the wire. As the impedance of the coils equaled R_{12} = 180 kilo-ohms and R_{18} = 650 kilo-ohms at 1000 cycl/sec after they had been completed, a reduction of this inefficient impedance had to take place. This was obtained by removing the insulation at the sides of the coil thereby forming a small path to be covered with a conductive varnish and thus short-circuiting the single layers. By this the impedance was reduced to a tolerable figure while the mechanical data was not altered.

In order to check the proper performance of the coils when in action - especially to prove that the line was not broken - a controlling apparatus was installed experimentally by us in the carrier planes. For this putpose a DC was imposed to the line, additionally to the controlling frequencies. This DC was inserted at the midtaps of the secondary windings of the cable adapter of the carrier plane and carefully registered. This control apparatus drew our attention later to an unexpected effect: the remote control system performed also satisfactorily after one wire had been torn, in this case the circuit being closed across the capacitances of the plane and the glider. Although this discovery did not offer a new control system, as a one-wire-system easily might be interfered by enemy signals, it seemed to contain new possibilities referring to fusing systems controlled by distance-meters. (e.g. HS 298). I therefore took up the research of this effect carefully toward the end of 1944, by means of capacitances attached to kite-balloons, but this work could not be accomplished in consequence of growing war difficulties and our evacuation from Berlin in the beginning of 1945.

At last a brief reference might be made to the remote control system by wire developed by Dr. Kramer for his "X4", as this system known as "Düren-Detmold" also had been examined by us. This system operated only by relays, was much simpler than our "Dortmund-Duisburg" equipment, but had the great disadvantage of only working on small ranges up to about 6 km. Therefore this system only interested us in regard to our HS 298.

<u>The Special Equipment for the Glider with the Remote Controlled Fuse. The Fifth Channel of the HS 293 H.</u>

In order to use the HS 293, which was available in large quantities, as an emergency anti-aircraft-weapon in 1943 a special system for the additional remote control of the fuse had to be developed. This had to consist of a simple accessory which easily could be attached to the standard HS 293. Also, a small time delay and precautions against enemy signals were demanded.

This task was solved first in the spring 1943 by establishing a fifth low frequency channel to the "Kehl-Strassburg"-system working at 3400 cycl/sec. For this purpose an additional circuit was installed for the modulator of the carrier plane, while the low frequency section of the receiver E.230 was provided with a fifth circuit resonant to the same frequency. This receiver was called E.230 h/i (or partly by mistake E.230 i). But this system didn't seem safe enough regarding possible enemy activities as, in this case, the transmission of a second carrier wave heterodyning the first to be an intermediate frequency of 3400 cycl/sec would already have fuzed the bomb.

Therefore, soon after, a new system was developed. In this case the transmitting and receiving units remained unaltered. The carrier plane was equipped with an additional 50 cycl/sec generator, whichwhen operated substituted the 10 cycl/sec switching process of the control stick transmitter for one control component, thereby switching two of the modulation frequencies in a 50 cycl/sec rythm.

On the receiving side a corresponding relay circuit was inserted in the controls for operating the fuse by means of a special safety circuit. These ideas were later also made use of in the receiving E.232 Colmar in order to obtain an additional control for the HS 298 resp. 8 - 117.

A further suggestion referring to this matter by Obering. Sturm was later made use of. This was the possibility of gaining several additional control channels by means of a phantom-circuit, this idea being established in the accessory to the receiver E.531. Briggs with the designation "Kanu".

Smaller series of the HS 293 Al were altered in 1943/44, especially in the manner described first, to HS 293 H's. In practice the control signal for the fuse was given by a fighter accompanying the carrier plane. But trials were also made to fuse the bomb directly from the carrier plane by means of the radiolocation apparatus "Neptun" installed therein.

The Special Equipment for the HS 294. (HS 293 C)

The Electric Fusing System.

The 2-ton glider HS 294 and the smaller edition thereof, the HS 393C, were designed for attacking ship-targets with the intention of hitting them below the waterline. For travelling under water the fuselage front section shaped like a torpedo was separated from the other parts of the glider.

The electric equipment for the controls of the HS 294 resembled those of the standard model HS 293 Al with a few differences owing to the size of this model. Because of the greater load on the ailerons two magnets in parallel for each flap were needed. For the same purpose the current in the field windings of the elevator motor had to be reaised. Also the two rocket motors provided had to be ignited. But all this mainly concerned only the connecting apparatus (Sammelgerät), and for this case a universal model SAG 230 had been constructed, which also fulfilled the demands of the HS 294. But the main difference referred to the fusing system, as this had to serve the following purposes :

1) after a safety time the whole fusing system was to be live.

2) as soon as the glider touched the surface of the water, the wings and the rear section containing the control apparatus were to be blown off.

3) the front section travelling then as a torpedo under

water due to its kinetic energy, has to have a fusing system of its own, which

a) after travelling a certain distance (d_1) becomes live,
b) ignites the explosives if the front section hits the target, and
c) ignites the explosives after travelling a certain distance (d_2) in case the front section has failed to hit the target.

In 1942 we designed in collaboration with Rheinmetall-Borsig, Breslau, a fusing system ("Möve" ?) to meet these conditions. In this, at the moment the carrier dropped the glider (t_0) an RC-circuit was loaded, which after a time constant (t_1) connected the power plant of the glider to the whole fusing system. Thus (at t_1)also the fusing system for the blow-off of wings, and rear section became live. When the glider touched the water surface one of the three feeler-contacts fitted beneath the glider energized the detonators attached to the wing spars and to the fastenings of the rear section. Before the front section had been separated (at t_1) a condenser herein was loaded by the power plant. Then after the front section had cruised under water for a distance (d_1), the fusing system for the bomb explosives became live by means of a water wheel attached to the front of the torpedo moving a contact. If the target was hit, the explosives were ignited by means of an acceleration switch, otherwise, the explosion was automatically obtained by means of the water wheel contact after reaching the distance d_2. (I don't remember the figures for the different values of t and d, but I know that the distance d_2 was so chosen that a torpedo which missed the ship might explode in the vicinity.

Trials carried out in 1943 with this fusing system proved that the blow-off fuse system failed to work, most probably in consequence of the reaction time, and the wings were generally torn away by the force of the water. Prof. Wagner therefore decided to do without the fusing system for the wings and rear section and replaced it by preparing the spots designated for breakage by weakening the material. Therefore a new simplified fusing system concerning only the explosives could be chosen. Also special safety measures towards the screening methods had become necessary, as the large currents feeding the lateral magnets (in the extreme 30 amp for one wing!) influenced the fusing system by induction.

The new fusing system incorporating these demands was ready by the end of 1943 and quite successful trials were consequently carried out. But the work on the HS 294 was never completed perfectly in consequence of the uncertain attitude of the air ministry towards this weapon, which often changed from one extreme to the other. At last in 1944 the plan was also considered of using the front section alone by dropping it from low flying torpedo bombers without remote control, but Prof. Wagner did not think much of this idea.

Finally, it may be briefly remarked, that a lot of work by Prof. Wagner's staff had also been put into the hydrodynamic research of the front section of the HS 294. For this purpose in 1941 a large water-channel was built on our grounds at Berlin-Schönefeld, equipped for taking high-speed motion pictures of model-projectiles in order to trace their way under water. These studies seem to have been very successful.

Standard Model HS 293 A1
Plan of Principal Parts.

- **Fuselage Front Section**
  - Fuselage
    - Fuse
  - Right wing
    - Magnet
    - Flap
    - Plug f. coil
  - Left Wing
    - Magnet
    - Flap
    - Plug f. coil
  - Rocket motor

- **Fuselage Rear Section**
  - Fuselage covering
    - Pull-off-plug
    - Aerial transf.
    - Plug f. rocket
  - Apparat. Board, right
    - Gyro & Potentiometer
    - Connect. apparatus
    - Battery
    - Converter AC
    - Cable adapt.
  - Apparat. Board, Left
    - Receiver
    - Filter & Relays
    - Converter, DC
  - Elevator unit
    - Motor
    - Gear
    - Potentiometer
    - Damping motor
    - Drag-meter
  - Tail surfaces
    - Elevator flap
    - Flares & lamp
    - Aerial

The 8 - 117.

The apparatus 8-117 was designdd as a remote controlled anti-aircraft rocket for fighting flying targets from the ground. It was the latest of Prof. Wagner's glider constructions, containing the most extensive equipment in consequence of the task to be fulfilled.

Structure of the Fuselage.

The plane has a length of approx. 4 m and a span of about 2 m. The cylindrical fuselage has a diameter of approx. 400 mm and consists of the Front-section, the Centre-section and the Rear-section. The Front-section, possessing a double-pointed peak, contains the apparatus for the controls and the fusing system. In the double-pointed peak the generator driven by an airscrew and the electric distance-meter for the fuse are situated. The aerial system of the latter, being fixed to the one peak, extends in the longitudinal axis to a length of about 70 cm.

The Centre-section bears the fuel-tanks for the cruising rocket motor, whilst above and beneath the fuselage centre section the two launching rockets are mounted, which possess a diameter of 120 mm and a length of 2 m each. Besides this, the spars for the tapered wings are fastened to the centre section. The wings bear the magnets for the lateral flaps.

The Rear-section with the attached horizontal and vertical tail surfaces contains the combustion chamber and the exhaust jet with the speed regulator, the latter controlling the opening of the jet. The elevator unit consists of two flaps controlled by two magnets. Like all Prof. Wagner's constructions no rudder is provided. The twin aerial system for the Colmar or Strassburg receivers (6 and 4 meter-band) is fixed to the tips of both wings and to the leading edge of the vertical tail surfaces, here terminating in the two aerial transformers. In case of installing the Brigg receiver (decimeter-band) a special dipol with reflector has to be attached to the tail surfaces. Also two flares of 120.000 candle-power are fixed to the rear section. While the pilot transmitter for radiolocation is mounted to the horizontal tail surfaces. A detailed scheme of the different accessories is shown at end of report.

Launching, Power Plant, Ignition - and Fuse-system.

The apparatus lies on the launching carriage, this having an angle of incidence in accordance to the desired flight path. It is electrically connected with the controlling system on the ground by means of the pull-off-plug attached to the gyro unit. This plug being accessible through a hole in the covering of the front section. Also a cord each for the release of the gyro system and for the start of the timing device (T10) are attached to the launching bed.

t = -3 min. At least 3 minutes before the launching the apparatus must be energized with 24 volts for the filaments of the valves and for starting the gyro. This time corresponds to the use of the decimeter receiver Brigg. (If a u.s.w. receiver like Colmar or Strassburg is employed the time required is only 2 minutes). The electric supply is attached across terminals 1 (-24v) and 6 (+24v). See Photocopy of "Leitungsplan Hs 117OC-O" in this report, or drawing of 8-117A1.

t=0 When pressing the starting knob 48 volts are connected across terminals 1 (-) and 4 (+48v) of the pull-off-plug and led to the generator, the latter beginning to work as a motor with a flywheel. The relay for pilot transmitter "Rüse" switches 210 volts on and "Rüse" begins to operate. (See drawing of "Leitungsplan 8-117A1").

t=5.5. sec. After 5,5 seconds, retarded by the relay in series with the starting knob, 24 volts are connected to terminal 7 of the pull-off-plug for the ignition of the bottom launching rocket T3, thus igniting it. The apparatus is then launched and the pull-off-plug separated. Released by cord
a) the timing device T10 starts to work and
b) the gyro-system K1 is released,the switches a-b to g-h (resp. i-k) turn over, and in consequence :
1) the generator A1 begins to feed the system
2) the top launching rocket T2 is ignited,
3) the 24 volt supply for the lateral and elevator magnets is connected. The controls are in action.
4) Ignition of the clockwork in the fuse S1 releases the timing device, the latter starts working.

t=10 sec. After 10 seconds the fuse is ready for action (entischert) and the apparatus is live (scharf)

t=11 sec. After 11 seconds the switch in the timing device T10 is closed and consequently :
1) the fusing system T7 is energized and thereby both launching rockets are blown off,
2) the cruising rocket motor T5 is ignited,
3) the speed-regulator T11 is set in action to control the velocity of the remote controlled live apparatus to a constant Mach-number,
4) the flares C1 are ignited

t=10 sec. to The release of the detonator in the fuse of the bomb by means of the electric distance-meter occurs when the t = 105 sec. apparatus passes the minimum distance below the limit of sensitivity of 7 m from the targets centre of gravity. The detonation can also be obtained by means of an additional control signal working a special relay and the unit called "Kanu" belonging to the Brigg-receiver. After 105 seconds the detonator is automatically set in action by means of the fuse S1. An automatic detonation is also provided as soon as the controls fail to work, this being achieved by means of additional contacts in the gyro unit, which are operated as soon as the gyro range (approx. ± ~~1700~~ 170°) is exceeded.

Details about the different Electric Apparatus.

Receiver (F1).

In the latest design for the 8-117 A1 ready for production in March 1945 the installation of three different receivers (wireless) was provided. These receiver types were :

Colmar E232
Strassburg - 3 (E 230-3)
Brigg E 531.

The employment of a receiver for the control system by wire had not been planned at the time.

Colmar E 232.

Manufactured by Friesecke & Höpfer, Berlin-Babelsberg. This firm took up work on this construction in 1941 and it was meant to be smaller and simpler than the Strassburg E.230 and especially fit for the models Hs 298 and 8-117 when cased in a cylindrical box. But because of lack of experience, the developing firm produced after a time of nearly two years a set that hardly served the purpose. For instance, the temperature compensation and the sensitivity of 50 u-volts were not sufficient. The apparatus worked on the superheterodyne system having approx. the same amount of valves as the E.230. The output stage was fitted with two Siemens T-relays (type 64p.TBv 3402/5). An AVC was installed but no AFC. The four low frequency channels were the same as in Strassburg E.230. (1000, 1500, 8000, 12000 cycl/sec). Owing to our new controls the switch frequency was 25 cycl/sec for the lateral component and 5 cycl/sec for the elevator. The apparatus had originally been designed for one wave channel only, in the "Kehl" - frequency range but this was lately changed to nine fixed selectable channels, in that two sets were provided, the one E.232.a and the other E.232.b, being adjustable to four and five different fixed channels, respectively. On request of the FLAK a third type, the E.232-1 operating with a few channels on another wave range was planned. The Colmar receivers were equipped for the transfer of a fifth channel.

Strassburg E.230-3.

The Colmar receiver was later to be replaced by this set, designed by Obering. Sturm, Strassfurter Rundfunk Ges. The E.230-3 was a six-valve super regenerative apparatus with a sensitivity of about 1 u volt (checking standard 10 u volt). AVC installed, but no AFC. Wave range about 4 m-band. Fifth channel by means of changing switch-frequency to 200 cycl/sec. resonant circuit therefore provided. The receiver had the same box, plugs and fastenings like the planned receiver Brigg E.531 and could be exchanged easily.

Brigg E.531.

Decimeter receiver planned by Telefunken GmbH, Berlin, but not accomplished. As a completed set never had been handed over to us, details cannot be issued. Our reactions towards this apparatus especially regarding the qualities affecting the controls were fixed in our : "Abnahme-Bedingungen für Kogge" in the beginning of 1944. Kogge was the designation for the Telefunken decimeter apparatus containing the transmitter "Kran" FuG 512 and the receiver "Brigg" E.531. To the latter the accessory "Kanu" belonged for obtaining the reception of the fifth channel. It is supposed that the Kogge-system was more or less ready for practical tests in march 1945 as Telefunken had asked us to get 50 gliders HS 293 V8 equipped, with which these trials were going to be carried out.

Apparatus Unit.

It consists of: the apparatus board V1,
the generator unit A1,
the gyro unit K1.

The Apparatus Board V1. serves for mounting and connecting all apparatus in the front section. The board, standing vertically to the longitudinal axis is fastened by means of two pins to the covering of the front section. The generator unit K1 and the gyro unit K1 are fixed firmly to the apparatus board, while the receiver F1 and the distance-meter T9 are exchangeably attached to it. The apparatus board contains the following parts belonging to the controls:

a) the filter for the lateral control operating at 25 cycl/sec, consisting of two condensers of 15 uF each across the double-potentiometer of 2x6500 ohms (placed in the gyro-unit K1) and of one resistance of 5 kilo ohms. This new extremely simplified filter, designed by Dr. Mühlbacher of my own staff, could only be attained by raising the control-stick-switching-frequency still more up to 25 cycl/sec. While the old large filter for 10 cycl/sec of the ASG

30 and 250, as used in the gliders HS 293 V2 - A1, contained various condensers amounting to a total capacity of 100 uF and also two twin choke coils, the filter for the 16 cycl/sec of the HS 293 A2 possessed seven condensers with a total capacity of 50 uF and two twin chokes, this latest design for 25 cycl/sec only needing two condensers of 30 uF together and one resistance. While the filter for the old control system HS 293 V2 - A1 had to be layed out to allow a certain AC-rest-voltage for moving the flaps at signal ratio nil, the new system could avoid this by means of the self-oscillating damping circuit.

b) the relays for the lateral control. Type Siemens Trls.64p TBv3410/5.bearing two coils I & II of 9000 ohms and 22.000 windings each and a special adjustment rendering a sensitivity of 1-2 μW. (0.4-0.9 volt). While the one coil was fed by the control voltage appearing across the two taps of the double-potentiometer, the other was energized by the damping voltage derived from the load of the damping circuit.

c) the damping circuit for the lateral control, composed of coil II of the relays referred to under b) and an RC-circuit switched by this relay, the circuit consisting of one condenser of 4 uF and two resistances of 20 kilo ohms each. This self-oscillating circuit operating at about 15 cycl/sec is energized by the voltage also appearing across the magnets. In order to obtain the proper phase shift the time constant and the feed-back voltage are dimensioned so that at an angle of about 30 degrees to 35 degrees before the determined angle of the rolling glider is reached, the accelerating rolling moment is diminished by operating the flaps shortly in an opposite direction. But besides this the following had to be examined by wind-tunnel tests. The size of the condenser and of the resistances in the damping circuit also determine the reaction speed of the controls and the stability of the flight around the longitudinal axis, providing the rigidity of the automatic control. This can be measured by the "switching-range," that is, the angular range of the counter-control formed by superimposing the damping signal and the control signal. In this case an angular range of ± 35 degrees was established, while towards the stability a pendulous movement around the longitudinal axis up to angles of ± 3 degrees was tolerated. The demand for the rigidity was this: in case of a disturbance amounting to 50% of the whole rolling moment the deviation of the lateral angle must not exceed 6 degrees. This was also proved in the wind-tunnel.

d) the lateral spark suppression circuit, consisting of a condenser of 5000 pF and a resistance of 1000 ohms in parallel across each relay switch and a resistance of 200 ohms across each magnet coil, both being shunted by a condenser of 0.25 uF.

e) the elevator spark suppression circuit. As the inter-stage relays planned between the receiver output and the elevator magnets could be left out - the receiver relays being found capable of controlling the magnets directly - only a spark suppression circuit for the receiver relays was needed. This resembled the circuit described under d), in which the two 5000 pF condensers are mounted (in this case, however, in the receiver in order to put them as near as possible to the relay switches). Although these spark suppression circuits may appear to be rather a trifle, they had to be layed out with greatest care and examined for a long time before it could be stated that the operation would cause no trouble. The difficulties arose in this case by the quality of the contact material in the relay switches, and as platinum was not available several substitutes had to be examined. After using gold-nickel contacts for many years, we found silver to be the best material for our purpose. Therefore, the relays employed by us at last were all fitted with silver contacts (relays type 64 p).

f) the relay for the pilot transmitter "Rüse," is energized after the starting knob has been pressed by means of the 48 volts applied to the generator and serves the purpose of then switching the 210 volts to the pilot transmitter in order to have the oscillator working stable when the launching takes place 5.5 seconds later. (For more details see section "pilot transmitter Rüse FuG 516").

g) the socket for the fifth channel relay or "Kanu"-plug can be used alternatively :

1) To use the receivers E.232 or E.230-3, a relay is placed here, which is energized by the impulses from the receiver terminals 2 (ZKI) and 7 (ZK2), thereby closing the relay switch across the leads A-la and Z-4a to the distance-meter T9. This results in a closing of the fusing relay for detonating the bomb.

2) To use the receiver E.531, the plug for the "Kanu"-apparatus is inserted here. This unit contains a relay which, in case of the raised switching-frequency appearing across its input terminals 1, 3, 10 feeds the following circuit resonant to this higher switching frequency. In a rectifying circuit coupled to the resonant circuit a condenser is then charged which operates a second tensioned relay. This connects the terminals A-Z thereby also closing the fusing relay.

h) the receiver plug is attached to a frame, which can be twisted to an angle of 90 degrees in order to fit the receivers E.232 as well as the E.230-3 and E.531.

The Generator Unit Al.

This is the only power plant of the glider after having been launched. It consists of :

a) the generator, built by AEG, Berlin, with the designation RR 75/II. This 250 watt generator provides, by means of two armature windings, 24 and 210 volts DC. Attached to the generator is

b) the regulator and filter. The regulator operates as a Thyrill-system for maintaining a constant tension on the 24 volt side, the 210 volts remaining without a regulation. (Lately it had been planned to fit the regulator to the 210 volts circuit instead of to the 24 volts, as a constant tension here seemed of greater need). With respect to the distance-meter a filter for smoothening the 210 volts had to be employed. The glider being in full action the generator is loaded to the utmost, the current on the 24 volt side exceeding 9 amp. The whole system is driven by

c) the airscrew with attached flywheel. In consequence of the great speed range of the airscrew (n = 7000 to 14,000 revol./minute) it had to be fitted with a variable pitch, as the electric regulator cannot compensate this large range by itself. In order to avoid a parasitic air resistance of the airscrew during the starting action while the generator is energized by 48 volts working as a motor, a free-wheel-clutch was fitted between the generator and the airscrew. After the start of the glider a flywheel attached to he airscrew prevents a speed drop of the latter until the rockets have come to full action.

The Gyro Unit Kl.

This apparatus, type HV10, built by Horn at Leipzig for the glider 8-117 consists mainly of the gyro itself, the double-potentiometers and some auxiliary parts, all fitted in a screened box.

a) the gyro itself, the Horn type HV7, contains a DC-motor requiring 24 volts and 0.5 amp reaching a normal speed of 18.000 revol/min. after a time of approx. 50 sec. The axis of the gyro frame in the longitudinal axis of the glider is coupled by means of a clutch to the axis of

b) the double-potentiometer, type Lpt 5, especially designed by the Askania-Werke Berlin for the controlling system of the Hs 298 and 8-117. Each of the two combined potentiometers has a resistance of 65,000 ohms, the resistance ratios of both must be equal for all angles. A special device is provided for adjusting the potentiometers at resistance ratio nil to the axis of the unreleased gyro frame.

c) the gyro compensating motor (Nachdrehmotor) is an additional equipment of the 8-117 gyro only. This gyro control motor maintains the gyro axis in the plane, which is vertical to the longitudinal axis of the glider. It therefore prevents the gyro axis from coinciding with the flight direction. This is done by means of a small reversible motor (List, type Mog), which by means of a cog wheel gear moves the lateral axis of the gyro frame. This motor is energized by a contact system, which is controlled by the gyro frame.

d) the pull-off plug is attached to the gyro box. The seven terminals conduct power to the glider before it is launched and allow the receiver to be checked by means of terminal 5. As soon as the pull-off-plug is separated and the gyro released.

e) the change-over-switch connected thereto is operated. By closing the switches a-b, c-d, e-f the + 24 volt lead from the generator to contact b is distributed and feeds across a the two gyro motors; across a to 6 (the distance-meter T9 and the receiver F1); across a, c, d, 12(the timing device T10, the controlling circuits and magnets, the top launching rocket T2 and the fuse S1), across a,e,f, 11 (the contact 6 of the generator), thereby short-circuiting the resistance in series with the field windings thereof. By means of the control g-h the + 210 volts from the generator is supplied to the distance-meter T9 and the receiver F1, while the i-k contacts, added later when the pilot transmitter "Rüse" was installed, switch off a resistance across terminals 9, 14 of K1 for balancing the 210 volts for the time that the "Rüse" is the only load of this cifcuit.

Note to a): Only at last was the device for automatic detonation in case of control failures added to the plan. For this purpose special contacts were attached to the frame of the gyro, which are closed as soon as the glider rolls to either sides reaching the limits of the angular range of the frame (approx. 170 degrees to both sides). The closing of these contacts connects the terminals 15, 16 of K1 thereby also connecting terminals 1a, 4a of T9 thus fusing the bomb.

The Distance-Meter T9.

The gliders 8-117 and HS 298 had to be equipped with a fusing system which was automatically controlled by a distance-meter. This fusing system had to come into action when the glider had reached a certain minimum distance to the centre of gravity of the target. The minimum distance was chosen at 6 - 7 m, thereby fixing the sensitivity range of the apparatus. The distance-meter had been for a long time the weak point of the gliders equipment, therefore the installment of various models had been provided, these were :

Kakadu (FuG 570)
Marabu
Fox
Meise

Besides these, numerous other types were planned by different firms, but nothing was positively known about them, especially regarding their usefulness, which was generally most doubtful.

Kakadu (FuG 570)

Manufactured by Donag, Vienna. Designed already in 1942, being one of the oldest types. The system works on the Doppler principles and employs a 2-valve-transmitter combined with a 3-valve-receiver. The transmitting- and receiving-aerials are also combined, this resulting in screening difficulties. Sensitivity range approx. 6 m. Afforded supply: 24 volts, 0.3 amp and 210 volts, 45 mamp.

Marabu.

Manufactured by Siemens, Berlin. Small edition of the well known airplane-distance-meter FuG 101 working with frequency modulated impulses. A draw back is the employment of three aerials. In consequence the installment of the two receiving-aerials attached to the wing tips of the glider had to be provided for, while the transmitter aerial remained in the front section.

Fox.

Manufactured by AEG, Berlin. Designed by Dr. Hilpert. 2-valve apparatus working on Doppler principals. Wavelength 1.80 m, sensitivity range about 6-7 m. In this system the reflected energy is received and demodulated by means of non-linearity in the transmitter circuit. By means of a condenser in the output circuit a differentiation is obtained, thereby achieving an exact timed steep voltage-curve. The same construction was applied by Patent Verwertungs-Gesellschaft at Salzburg.

Meise.

As no apparatus ever had been available for us, no details can be remembered.

For a long time these devices, especially Kakadu and Fox had been tested by us. This was generally done by flying an airplane close above the apparatus to be examined, the latter being mounted on a high fire-ladder. The minimum distance between plane and apparatus being checked by photographic methods while the operation of the distance-meter was oscillographed. But several other methods were in use, it being most difficult to find a corresponding model for examination in the laboratory.

Fuse S1.

Manufactured by Elektromechanik GmbH, Reichenberg (and by Preh at Neustadt/Saale). Type 96A for HS 298 and 96B for 8-117. Especially designed by us in collaboration with firm mentioned. As the distance-meter in the moment of operation only closed a relay switch, a special fuse had to be designed with respect to the various demands that were required ~~for case of~~ for safety. Owing to our experiences a normal fuse placed in a remote controlled bomb must be regarded as a source of peril. Both fuse types 96A and 96B were of the same construction and contained a switching device operated by a clockwork. The only difference referred to the switching times. After the releasing impulse over plugs S3, S2 has reached the fuse S1 a small detonator herein is fused, thereby removing a pin and a clockwork setting. This clockwork moves a small disk bearing a cam by which four switches are operated. At the time $t = 0$ the bomb detonator is short-circuited and the screened connection to the distance-meter is open, at time t_1 the detonator is connected to the distance-meter and also to the acceleration-switch in the fuse S1, thus the fusing system is live. At this time if the distance-meter-switch or the contacts on the gyro frame or the 5th signal switch or the acceleration switch in the fuse - all being in parallel - are operated, the detonator explodes the bomb. At the time t_2 the detonator is switched across a condenser for automatic explosion, the condenser was switched on to be charged at t_1. At the time t_3 the detonator is short-circuited again, all leads are cut off, in order to prevent the blind bomb from exploding when touching the ground. The various times for the two fuse types are :

	type 96A (HS 298)	type 96B (8 - 117)	
t_0 =	0 - 6 sec.	0 - 10 sec	(Blind)
t_1 =	6 -51 sec.	10 -105 sec	(live)
t_2 =	51st sec.	105th sec	(self detonation)
t_3 =	51 sec.	105 sec	(blind)

Timing device T10.

This is the same clockwork system as used in the 8.8 cm Flak-shell, and is released by a cord when the glider is launched. After 5.5 sec the clockwork closes the switch and thereby energizes the fusing system T7 for blowing off the launching rockets, ignites the cruising rocket motor T5, feeds the speed regulator T11, and ignites the flares C1.

The magnets for the Lateral Flaps K2, K5.

The magnets operating these two flaps are of the type MBK 2x1b-2, manufactured by List, Berlin-Teltow. They are double-stroke types bearing two coils, the middle-position being obtained by means of springs. This type had - like all other magnets - to be especially developed to fulfil our demands. Energized with 24 volts, 20 watts, the time required for the move from one extreme position to the other equals approx. 25 m/sec, while the time-difference between the time required for the move in one direction and the time needed for the other did not exceed 1.5 to 2 m/sec. All this data had to be carefully examined before the magnets were used, as they had great influence on the controls. Owing to trials with different types of Wagner-flaps the magnets were often exchanged in the beginning.

The Magnets for the Elevator Flaps. K8, K11.

In this case two magnets connected in parallel moved the elevator flaps. The power need for one magnet was in this case 31 watts at 24 volts, as a different more powerful type had been installed here. (Magnet type: List MBK 2x2b-2). All other details resembled the characteristics of the lateral magnets already explained.

Speed Regulator T11.

This device for obtaining a constant cruising speed of the glider consisted of an aerodynamic speedometer working upon the known principles, by which a relay was operated which controlled a motor for regulating the opening of the jet. The apparatus was designed by our own staff.

Pilot Transmitter Rüse FuG 516.

This apparatus pertained to the control of the glider by means of radiolocation principals instead of direct eye-sight. As the reflecting surface of the 8-117 was too small to maintain useful results with growing distance, the installment of a small pilot transmitter was necessary. The Telefunken GmbH Berlin, which was responsible for the outfit of the control station for the 8-117 on the ground, therefore asked us to attach the "Rückstrahlsender FuG 516 (Rüse)" to the rear section of the 8-117.

Testing Apparatus.

As for the HS 293 production model we had also designed and built nearly all the apparatus for checking the various electric parts of the 8-117 and the HS 298 using nearly the same equipment. Control and testing instruments had been finished for checking the relays, the spark suppression circuits, the control circuits, the generator, the gyro, the potentiometers, the whole apparatus board, the magnets, the receiver, the distance-meter, the fuse and also the whole completed glider. But it is not possible to go into these details now.

Equipment of the Control Station on the Ground.

The ground station for the remote control of the 8-117 had been first planned by Prof. Wagner for control by optical sight by means of a telescope system, which was to be adjusted by a special man for the aimer, so that the latter only had to handle the control stick. As control stick transmitter, the new model described on page 11 was going to be employed. In the case of the 8-117, an accessory called the "Rolle" had to be attached to the control stick transmitter. By means of this apparatus the 8-117 just lanched was automatically ordered to roll over an angle of 360 degrees thus compensating for the lack of exactness in mass production models before the speed became high enough to obtain efficient control. Regarding the wireless transmitter we had used the old "Kehl"-system for our own trial flights, fitting also a "Strassburg" E.230 receiver in the 8-117. But this was not going to be the practice. The final plan for the control station on the ground was layed out by Telefunken in collaboration with the "Erprobungsstelle der Luftwaffe" at Peenemünde, and with us. For transmitting the decimeter "Kogge"-system with the transmitter "Kran" FuG 512 was going to be employed. A new feature of this transmitter was the AFC fitted therein, which tuned the transmitter to the receiver "Brigg" E.531 shortly before the latter was going to be used. (It may be remarked, that during the German retreat from Silesia Telefunken lost a transmitter "Kran", which fell into the hands of the Russians). By means of a radiolocation system Telefunken was going to make the control of the 8-117 independent of visibility conditions. The first control stations of this kind were meant to be delivered in the spring of this year.

I am not able to give more information about this equipment which had names like "Brabant," "Burgund," "Rheinland," "Elsass," etc., as this matter had entirely been layed into the hands of Telefunken, which was also in touch with all the other firms concerned for supplying the various accessories like counting-machines,etc. Herr Obering.Bialk was in charge of these equipments at Telefunken, and if he is not within reach, Herr Obering.Sturm, Strassfurter Rundfunk, former chairman of an advising commission to the airministry, might be able to give information.

The HS 298.

The glider HS 298 had been designed as a remote controlled anti-aircraft rocket for fighting flying targets from the air. For this purpose one or several 298's could be carried either by fighters or bombers. This model was constructed by Prof. Wagner at the same time with the 8-117 and had almost exactly the same electric outfit although it was very much smaller. As in the previous section of this report a detailed description of the 8-117 was given, here only a brief explanation will be necessary especially referring to the differences.

The HS 298 has a length of approx. 1.40 m and a span of approx. 1 20 m, the fuselage consisting of the front- and rear section.The front section resembled that of the 8-117, only smaller, and contained the same receiver, distance-meter and apparatus unit, the latter being simpler. The rear section with the attached tapered swept back wings of which only one bore a Wagner-flap,

operated by a double-stroke 20 watt magnet, contained the fuel tanks, combustion chamber and jet of the rocket motor and ended in the horizontal tail surfaces with Wagner-flaps as elevator, controlled by two 20 watt magnets in parallel. The elevator controls were lately altered and operated by only one magnet (MBK 2x2b-2; 31 watts), while the one lateral magnet remained (MBK 2x1b-2; 20 watts).
Attached to the tail plane were twin vertical fins but no rudder. The apparatus unit, being principally the same as in 8-117, differed in the following :

1) Instead of the Gyro unit type HV10 the type HV9 was employed, which contained no gyro compensating motor, otherwise being the same.

2) The pull-off-plug could be omitted as the generator was already set in action when the carrier plane started, an additional power supply therefore being superfluous.

3) On the apparatus board the relay for the pilot transmitter "Rüse" was not needed, no "Rüse" being required. (The damping circuit attached to the apparatus board could remain unaltered, as wind tunnel tests had proved that the damping of the rolling moment also, in this case, was sufficient).

4) The timing device could be replaced by a small retarding relay.

5) The fuse 96A had to be used owing to different times required in consequence of the much shorter flight path.

The elevator control magnet was fitted with the device referred to earlier for limiting the stroke thereof with an increase in speed. For the launching of the HS 298, no special launching rockets were needed, as the glider was either dropped by the carrier or catapulted from rails fixed to the carriers wings by means of its own rocket motor. In this case the igniting impulse for the fuse (SI) for releasing the clockwork was generated by a magnet passing a coil (Stossgenerator) while the glider moved along the rails. Thus it was determined that the fusing system could only be set in action if the initial velocity of the glider was large enough to cause it to leave the rails. In the case of dropping the glider from the carrier, a special relay was required, which with a certain time delay provided the igniting impulse and energized the elevator controls. The latter was a safety measure already made use of in the circuit of the HS 293 for preventing a collision between glider and carrier plane. A simplified circuit for the carrier equipment had been designed by us for this purpose, especially to obtain a relief for the bomb aimer by means of automatic devices. But the final planning of this equipment for the carrier planes was in the hands of the "Erprobungsstelle der Luftwaffe" at Peenemünde (Herr Schneider). Finally, the installment of a bombing apparatus had been planned for the future and we were in touch with the "Forschungsanstalt der deutschen Reichspost" at Berlin (Dr.v.Oettinghaus) on this matter, as this institute was working at this problem.

The 8-117 H.

This model was an experimental modification of the 8-117 planned with the intention of possessing a universal model that could be launched from the ground or dropped by a carrier plane. In order to study the launching by plane and the use of this type, it was equipped with the electric system of the HS 298, including the additional safety relay for locking the elevator control already referred to.

8-117 Al.

Plan of Principal Parts.

- **Fuselage Front Section**
  - Receiver F1
  - Appar. unit
    - Apparatus board V1
      - Lateral filter
      - Lateral relays
      - Damping Circuit
      - Lat.Spark suppr.
      - Elev.spark suppr.
      - Relays f.pilot transm.
      - Socket 5 chan.rel Kanu
      - Receiver plug.
    - Generator unit A1
      - Generator
      - Regulator & filter
      - Airscrew & flywheel
    - Gyro unit K1
      - Gryo
      - Potentiometers
      - Gyro compens. motor
      - Pull-off-plug
      - Change-over-switch
  - DistancemeterT9
  - Fuse S1
  - Timing dev.T10
- **Fuselage Centre Section**
  - Bot.Launch.rocket T1
  - Top launch rocket T2
  - Fuselage
    - Fuel tanks for cruising rocket
    - Blow-off device f.launch rockets T7
  - Right wing
    - Magnet K2
    - Marabu aerial
    - Flap
  - Left wing
    - Magnet K5
    - Marabu Aerial
    - Flap
- **Fuselage Rear Section**
  - Horiz.tail.surf
    - Elevator magnets K8 & K11
    - Elevator Flaps
  - Fuselage
    - Jet cruising rocket
    - Speed regulator T11
    - Flares C1
  - Aerial syst.F2
    - Aerial
    - Aerial transformer
  - Pilot transm.F3
  - Aerial syst.f.Brigg.

Designations of 8-117 models :

8-117A	=	experimental.
8-117B	=	experimental.
8-117C	=	experimental.
8-117 Al	=	1.serial model.
8-117H	=	special model.

Explanation

to diagram of connections "Leitungsplan HS 1170-0" (Oct.1944)

V1.......Apparatus board, containing: lateral control circuit (filter, relays, damping circuit, spark suppressor; intermediate relays for elevator with spark suppression (removed later) and 5th channel relays,

V1-1.....Plug for receiver F1
V1-2.....Plug for connecting the fuselage centre section
V1-3.....Plug for feeding fuse S1
V1-4.....Plug for feeding the distance-meter T9
V1-5/6...Plugs for connecting the timing device T10
V2.......Plug strip for connecting fuselage centre section
V3.......Distributing plug plate in centre section
V4/5.....Plugs for connecting centre section with rear section

F1.......Receiver with terminals (F1-1):

2...ZK1..........5th channel) for remote fuse control
7...ZK2..........5th channel)
5...Q-A..........lateral control: relays centre contact A
9...0 (-210V)....nil and -210 volts
10...-24V.........-24 volts
12...H-A..........elevator control: relay center contact A
1...+24V.........+24 volts
3...+210V........+210 volts
14...NF...........low frequency checking terminal
4...Q-T..........lateral control: relay side-contact T
6...Q-Z..........lateral control: relay side-contact Z
13...H-T..........elevator control: relay side-contact T
11...H-Z..........elevator control: relay side-contact Z
8...HF Regltg....high frequency control lead

F1-2.....Aerial plug
F2.......Aerial system
F2-1/2...Aerial transformers

A1.......Generator unit, containing generator and regulator with the terminals :

2......-24 volts
6......lead for short-circuiting serial resistance of field winding after generator in action
1......+24 volts
4......+210 volts
0......nil and -210 volts

K1.......Gyro unit, containing: gyro, double-potentiometer, gyro-control-motor, change-over-switch, operating the contacts:

a-b... the + 24 volts lead from generator arriving at 13 is distributed over b-a to c,e and feeds the gyro-motor and the gyro-control-motor-circuit and over terminal 6 to the appr.board V1 for supplying the receiver F1 and the distance-meter T9.

c-d... by closing these contacts 24 volts are led ov.12 to app.board V1 there supplying the timing device T10, the control circuits and over S3 the fuse S1, amd over V2 the distributor V3 thereby top launching rocket T2 and the magnets K2,K5,K8 and K11.

e-f....leads the 24 volts over terminal 11 to terminal 6 of the generator thereby connecting terminals 1 and 6 for short-circuiting the serial resistance of the field windings.

g-h....connects the 210 volts from terminal 9 to 10 thus energizing the receiver F1 and the distance-meter T9.

The pull-off-plug has the terminals for connecting the ground power plant etc:

1.....-24 volts.
6.....+24 volts for feeding gyro, receiver and distance-mtr.
4.....+48 volts for feeding generator for start
7.....-24 volts for igniting bottom launching rocket T1
2.....-210 volts and nil
3.....+210 volts
5.....Low frequency lead for checking receiver.

K2........Magnet for lateral flap
K3/4......Plug for magnet K2
K5........Magnet for lateral flap
K6/7......Plug for magnet K5
K8........Magnet for elevator flap
K9/10.....Plug for magnet K8
K11.......Magnet for elevator flap
K12/13....Plug for magnet K11
S1........Fuse
S2........Plug for fuse S1
S3........Plug on app.board for fuse S1
T1........Bottom launching rocket
T2........Top launching rocket
T3........Plug for T1

T4.......Plug for T2
T5.......Cruising rocket
T6.......Plug for T5
T7.......Blow-off-device for launching rockets T1 and T2
T8.......Plug for T7
T9.......Distance-meter
T10......Timing device for switching the blow-off-device T7, the cruising rocket T5, the speed regulator T11 and the flares of C1
T11......Speed-regulator
T12......Plug for T11
C1.......Flares
C2.......Plugs for C1
VRel.....Coil for retarding relay in ground control station
r1.......switch of relay VRel for connecting 48 volts to generator
r2.......retarded switch of relay VRel for igniting bottom laun.rock.

Additional designations in the diagram of connections "Leitungsplan 8-117 A1" - Serial model - march 1945,

F3........Pilot transmitter "Rüse" (FuG 516)
T9-3 to
T9-10.....accessory parts for the aerial system of dist.mtr."Marabu"
K1 contact
i-k..installed for pilot transmitter "Rüse" in order to switch off balancing resistance for 210 volts supply across 9,14 in K1
R-Rü.....Relays for switching 210 volts supply on for "Rüse"
Kanu.....receiving device for 5th channel, accessory to receiver "Brigg"

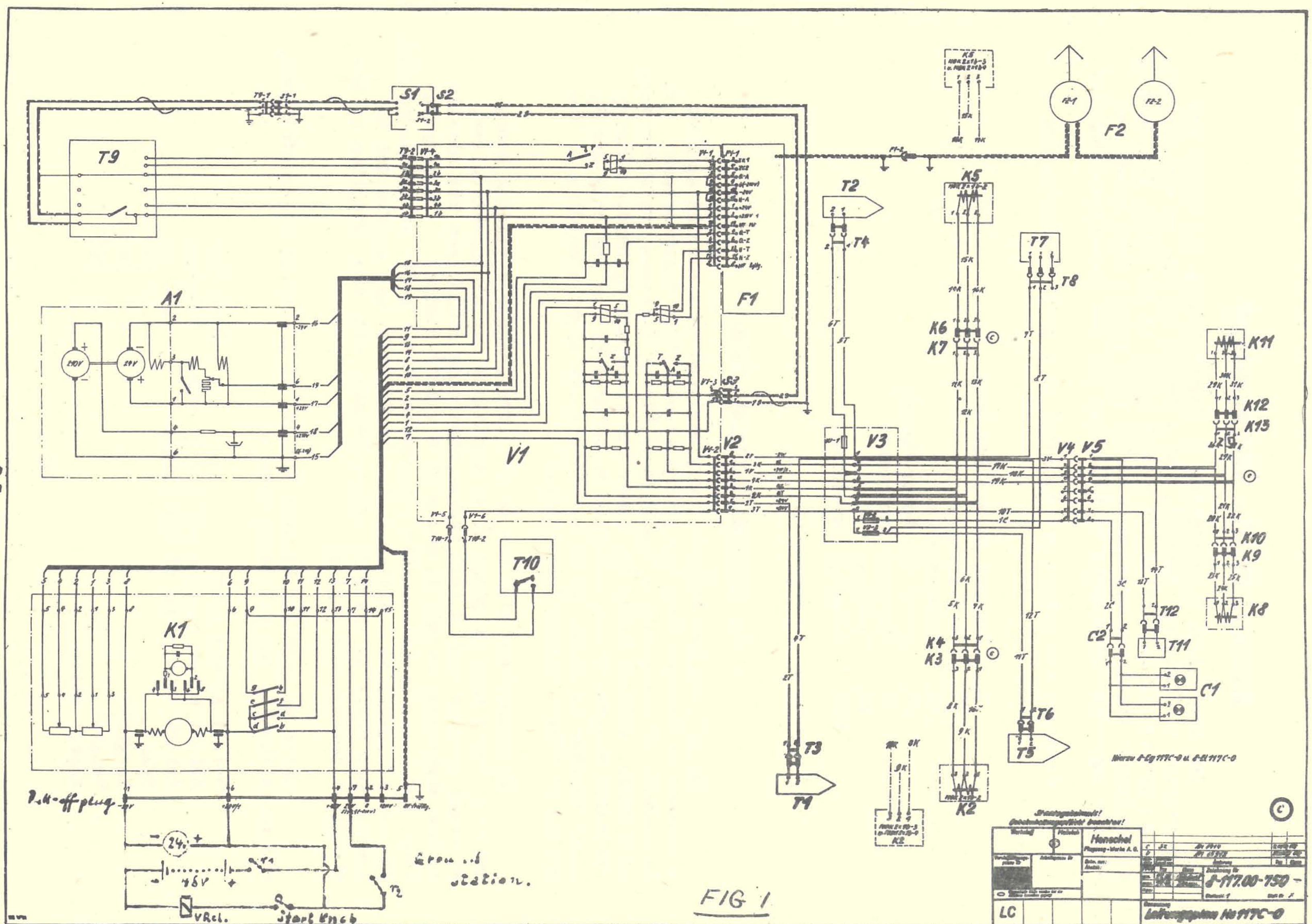

S1
S2
T9
A1
F1
F2
T2
T4
K5
T7
T8
K6
K7
K11
K12
K13
V1
V2
V3
V4 V5
K10
K9
K8
T10
K1
T12
T11
C2
C1
K4
K3
T6
T5
T3
T4
K2
24v
48V
VRel.
Start Knob
Ground station.
Pull-off plug
Henschel
LC
8-117.00-750
G 25253 TFV

FIG 1

Butterfly Hs 117. (Schmetterling)

The mechanical construction of Schmetterling was under the supervision of Dipl.Ing. Henrici, and a report written by him, follows. He has written an outline of his report which is included, followed by a supplement which was written to cover some points that were considered important by members of CIOS team 367 who interviewed Henrici.

Drawings and graphs are included as a part of this report :

I. General Survey and Data.
II. Performance.
III. Aerodynamics.
IV. Boost and Motor-Rocket.
V. Electric Equipment.
VI. Tactics.
VII. Intended Development.

I. General Survey and Data.

Hs 117, called Butterfly, was designed as a missile against airplanes to be used from the ground as well as from interceptors. It is capable of destroying a Boeing B-17 Flying Fortress, at a distance of 8 yards, without being too heavy for transport by hand. During its early stages, it was intended to be used by day and only during clear weather by night, as it was piloted by sight according to the method of "Three-Points-Coinciding."

By comparison with the Hs 293 (Prof.Wagner's gliding bomb) and with tests made by means of an appliance for aiming-exercises, we could promise that a well taught steersman could keep the missile on the sight-beam within an angle of 8×10^{-3} radians. By computation, and later by trials with components of the B-17, we concluded that 55-lbs. of powder at a distance of 8 yards were just sufficient to render most parts of the B-17 unserviceable, with the exception of the structure between the engines.

Later we resolved to take 90-lbs. of powder as the useful load, and got with this the following data :

Weight at the start	1000-lbs.
Weight after blowing off the boosts	600-lbs.
Weight at the end of the flight	440-lbs.
Span	2.19 yards
Length	4.5 yards
Height	1.1 yard
Aspect ratio	3.5

II. Performance.

To obtqin the least weight and the most performance, we chose a constant porportion of the velocity of sound as flying speed after starting. (constant Mach-number). For several reasons we did not intend to exceed the velocity of sound. We promised 0.75 of this velocity with the intention of increasing this percentage according to the result of trials.

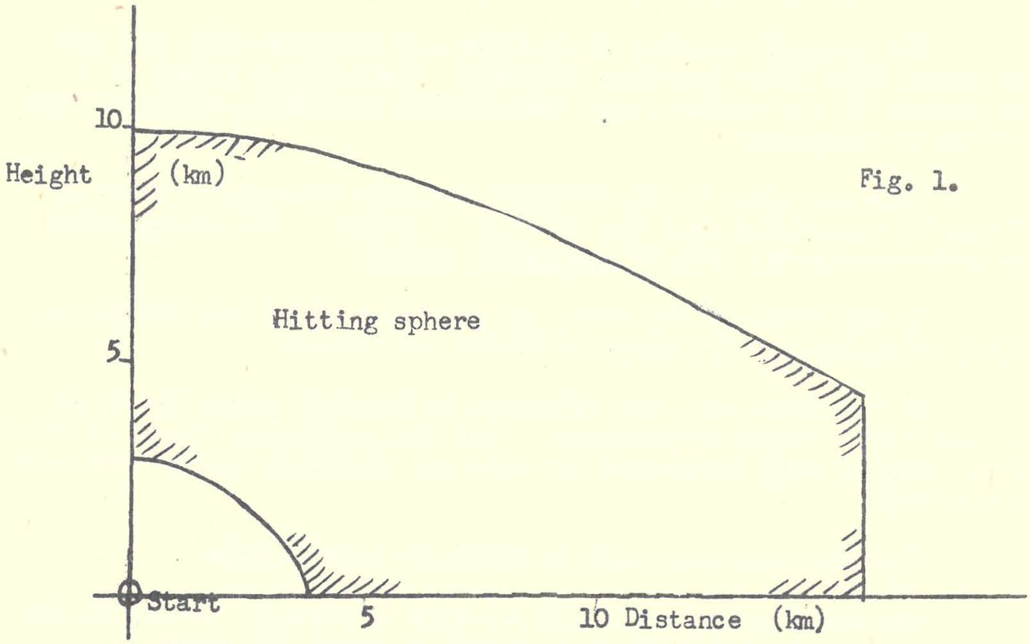


Fig. 1.

Looking at the graph fig.1, which gives a half-section of the sphere in which deadly hitting is probable, one sees just ~~start a~~ that region in which the missile is brought within a distance of less than 8 yards off the sight-beam. This may take about 20 seconds with a mediocre steersman. The other arbitrary limit depends on the required visibility permitting observance of the target and missile to keep within the allowed distance. The constant speed of about 0.78 times the velocity of sound is warranted until the upper limit. Beyond this limit its speed decreases.

A similar diagram was made for timing the shot according to the height and velocity of the attacking airplane. It was concluded, that the Butterfly could be aimed against planes with a speed not exceeding 340 miles per hour, taking into account the possibility of evading-manoeuvres. The maximum acceleration perpendicular to the wings was limited to about 7.5 x g by a special device, as more was thought to be unnecessary, even disadvantageous.

III. Aerodynamics.

The components of the missile are :

1) the fuselage with a circular cross-cut,
2) the wings with profile NACA 0012.0 825-40 and a sweep-back of about 40 degrees,
3) the tail-unit with the trapeze-shaped tailplane and fin.

The controls consist of elevator and ailerons only, and are not shaped like flaps but like spoilers: flaps with a height of a few percent of the medium chord, oscillating behind the trailing edge of wing or tailplane.

Care was given to the greatest possible symmetry as this is of special importance near the velocity of sound. The design, which was made in a hurry, left two asymmetric points:

At the front of the body, the generator-drive and the aerial of the distance-fuse are situated beside each other.

At the back-part, the tailplane is situated above the wings, and the body deformed accordingly. The last asymmetry was to be avoided by choosing some incidences for wing and tailplane against the axis of the body.

Several tests were made in different wind-tunnels.

One model to the scale 1:2 was made of wood and tested at the great wind-tunnel of the DVL up to speeds of about 100 miles per hour. There resulted the first changes of the situation of the tailplane and of the distance between the boosts.

One model to the scale 1:15 was made of brass and quickly tested at the high-speed tunnel of the AVA up to speeds of about 0.9 times the velocity of sound. They showed a satisfactory small change in the position of the resulting lift-force.

A third model to the scale 1:2 was made of alu-alloy and tested at the great highspeed-tunnel of the DVL up to speeds of about 0.85 times the velocity of sound. There appeared an agreeable conformity with the former results. The lift coefficient at the highest speeds reaches about

$$C_L = \frac{L}{\frac{\varrho}{2} v^2 S} = 0.5$$

All these tests and trial flights were made with a rectangular tail-plane, while the missiles of the production model were built with a trapeze-shaped stabilizer. Greater limiting speeds could be attained by this.

The characteristic graphs will be shown and discussed later on.

The accuracy of the manufactured product was carefully examined to avoid sources of defects as far as possible. For instance, the camber was not allowed to be greater than 0.2 millimeters nor the twisting greater than 0.1 m.

IV. a) Boost.

The Hs 117 is driven by two different rockets. The acceleration during the start depends on the thrust of two boosts which are fastened symmetrically above and below the fuselage. The variable thrust needed for flight with constant speed is given by motor-rocket built in the body.

A boost consists of an iron tu be with a jet mounted on a spherical flange, in which was a hollow pressed core of powder about 2 yards long and 6 inches in diameter. First, we used an inside-burning core, which gave much trouble by its great dependence on temperature and by irregular behavior. It corresponded in no way to the conditions laid down by us. Worst of all, they exploded when lit by temperatures over 77 degrees F. Later we got a new powder pressed in an all round burning core which did fairly well. Its chief drawback was the thick cloud of smoke preventing observance of the missile or the target. But that could have been overcome.

The boosts were fastened in such a way that they were blown off after burning by an automatic device. For the development of these boosts special conditions were demanded by us :

1) The momentum ought to amount to $7400 \begin{smallmatrix} +500 \\ -0 \end{smallmatrix}$ kg sec.
2) The time of burning 4 ± 0.5 sec.

Further conditions referred to time-delays and to the shape of the diagram: thrust versus time. The conditions of time and of delay proved the most difficult to fulfil.

IV. b) Motor-rocket.

The conception of conditions for new developments we thought to be one of our chief tasks. That may be seen in the case of the motor-rocket.

In an antiaircraft-rocket missile the motor-rocket is the most important component. Here it took 55% of the weight of flight, the body and wing about 24%, and the electrical apparatus about 7%, the remainder 19% being useful load.

Our demands on the motor-rocket were the following :

1) Momentum with medium thrust in the ground; 12500 kg sec
2) Thrust infinitely variable between 220 and 220 ± 160 kg
3) Automatic regulation for constant speed with an effective accuracy of 3% of the given Mach-number. For this regulation further conditions were put forth specifying time-delays and so on.
4) It must also work during accelerations of 10 x g perpendicular to the wings or ± 1 x g in the longitudinal axis.
5) The weight of the complete motor-rocket was not to exceed 330-lbs.

Further conditions referred to oscillations, visibility and so on.

According to these conditions the first motor-rocket was developed in 4/4 years, the regulator being made by ourselves. It was not satisfactory as the momentum with reduced thrust decreased too quickly and the friction of the slide-valve of the burning-chamber was too great. At last we thought we could design it with less weight. It consisted of a spherical pressed-air-container, two tanks with free moving pistons, a burning-chamber with two slide-valves, a thrust regulator and the usual outfit.

A few months later we got another design without pistons, and with a very promising uncooled burning-chamber. This firm made their own regulator mechanism. It was a hydraulic one, ours was an electric one. The momentum curve was very satisfactory. There were made no trial-flights with this motor-rocket due to the stoppage of our work.

V. Electric Equipment.

The most interesting section is in the pointed nose of the missile housing the electrical equipment. As the Hs 117 was to remain workable after a year's storage in an open shed, the electric current was provided for by a propeller-driven generator. Its veltages were 24 and 210 volts, with exacting conditions on its accuracy. Its strengths were 9 and 0.250 amperes. The current was needed by the receiver, the steering device with the gyroscope, the magnets by which the controls were driven, the thrust regulator, the distance-fuse, and by minor items. On the whole, the electric equipment is known from the gliding bomb Hs 293. After the final development, there ought to have been only about 5 electronic valves and a few relays.

To give a special command, the steersman moved a little control lever thereby changing the ratio of momentum of a meander-shaped current. In the measure of that ratio, audio-frequencies are switched by twos and the high frequency of the transmitter is thereby modulated. To each direction of the control-lever is attached an angle of bank and to each deflection of the control-lever is attached an acceleration. By the same means, the magnetoes of the elevator-drive are switched, while the aileron-drives get their momentum by way of potentiometers which are connected with the gyre. By this device the command to the magnetos is changed accordingly. The steering-frequency, given by the relay after the potentiometer, is conducted through an oscillating - circuit to a second winding of the relay. By this device, together with the rest-waves, the ailerons-steering was damped, and the delay of the command was reduced. The maximum angular acceleration was about 8 radians/sec^2. Here also very exacting conditions had to be fulfilled. Lastly, there was a little transmitter which could give either the position of the missile, or, during the trial-flights, any wanted measurement which could be expressed by two signs.

VI. Tactics.

Our battery consisted of two sets with 6 starting-stands each. Every set had one aiming-stand with a steersman and one observer. As a greater enlargement is accompanied by a smaller angle of view, the observer got a monocular with an enlargement of 6:1, while the pilot had two different enlargements of about 4:1 and 12:1. The oculars of both were connected, so that the observer always looked at the attacking airplane by moving his ocular and thereby caused the pilots ocular to point in the same direction. The telescopes and the seats were turning aroung three axis.

The starting-stands were designed so that the missile was instantly free from it as soon as the boosts were burning. The whole outfit was adapted to quick removal from one place to another without needing hoists or preparations on the ground. In case of an attack the chief of the battery told either of the observers where to look for the airplanes. When the chosen target came within range the steersman started the rocket and steered it, covering the objective till the missile exploded by means of the distance-fuse.

The distance between the batteries depended on the wave length, which was to be reduced.

VII. Intended Development.

The first drawback at the actual trial flights were the boosts, whose manufacture seemed obsolete compared with modern production models. No attention was paid, while rolling the core of powder, to the temperature of the rollers or to the quantity of passages. The

The dependence of the burning-time on the temperature of the core was partly overcome.

The second drawback was the receiver whose reliability was not sufficient.

The third was the distance-fuse, which ought to work with relative velocities from about fifty to about four hundred yards per second. At the same time it ought to be coded so that it could not be disturbed by transmitters of the attacking planes. Different devices were being developed: About two or three by means of high-frequency, two optic and two acoustic appliances. None of them were used during the trial-flights. Our chief task was to define the conditions under which they were applicable. The most essential progress would have been a satisfactory self-aiming device, whose development followed the same lines as the distance-fuse. With this the missile would have been independent of weather.

The velocity greater than that of sound, could be chosen, to which purpose favorable designs were already tested in the wind tunnel.

SUPPLEMENT TO THE SHORT TECHNICAL DESCRIPTION OF SCHMETTERLING.

This supplement contains a few remarks on the following topics touched upon during conversations :

I. Model.
II. Aerodynamic Properties.
III. Motor-Rocket.
IV. Manufacture.
V. Formula for Explosive-Charge.

5 sketches.

I. Model .

To understand best the following discussion of the graphs one should have well in mind the general outlay of the Butterfly as, for instance, given to the scale 1:15 in the last sketch of this paper. If one knows the first built design one will notice that the forepart is now somewhat longer, the distance between wings and tail unit is less, and the most important alteration, the rearpart has been newly designed. Of course the curves and sketches given can only be informative and are not to be considered very accurate as the author has no access to former reports, as except for a few chance remarks in his books - e.g. "Aerodynamic Theory" by Durand - he has to rely on his memory. However, he hopes that it will be sufficient to form a comprehensive idea of the Butterfly's properties.

The reasons for the changes mentioned above are self-evident. We will first have a look at the rearpart. In the first design, it was assumed that the light of the burning motor-rocket could be made distinct enough, to view the missile at a distance of about 6 to 10 miles. But the attempts to mix colouring chemicals in the fuel or to drop them in the gas-beam failed. We resolved to use a red flare giving about 60,000 H.K. at the start and about 200,000 HK in the later part of flight. This facilitated the decision to build a more wedge-like rearpart instead of the first circular shaped one.

By the windtunnel-trial made at the same time with the HS-293, we gained the opinion, that with high subsonic speeds the shaping of the aftpart of body is at least as important as shape and profile of the tailplane itself. Therefore, we paid special attention to the transition from body to rearpart.

II. Aerodynamic Properties.

The first model showed too great a sensibility to the approximation of the velocity of sound. A n analysis of the underlying causes, as given by fig. 3, made it evident that the fault was with the tailplane. The latter could not be made thinner as we were bound to use a drive for the controls which were already in production. We therefore changed from the rectangular-shaped to a trapeze-shaped tailplane with a sweep-back of about 35 degrees.

The graphs in fig. 1, 2 and 3 correspond roughly to measurements made with a model similar to this description, with the exception of the old-shaped rearpart; otherwise all is as shown in the last sketch. The complete model with all developments has been buried in the ground of the DVL; it was not yet tested. The measurements were made in the great high-speed tunnel of the DVL (Dr. Göthert). Fig.1 shows the characteristic curves of lift versus drag at the Mach-numbers 0,75 and 0,86. The lift with o,75 was, at the greater incidences, considerably higher than expected. With this high lift, the pilot was able to give low altitude accelerations far in excess of all that was needed. At the same time the different accelerations at different heights, with the same position of the control-lever, would have been more disturbing to the pilot. For that reason we undertook the regulation of elevator-deflection by the pressure head. For this purpose the little discs outside the tailplane were installed.

Of course one might have used an electric device as was done in other cases. But all the questions of a more electric nature - e.g. development of the control-lever are here not considered as they are covered by special reports of Messrs. Sturm, Marcard and others.

The dependance of drag on velocity is given on fig.2. Apart from some effect of Re-number, the increase of drag near the Mach number, 0,86 is remarkable. In fig.3 the change in position of resulting lift is even more striking.

It is interesting, that during over sixty starts of the missile in Peenemünde, when about twenty reached ma-numbers over 0,90 no deteriorating effect was observed. Making graphical and numerical solutions of trial-results oneself, one got the interpretation, that the missile behaved very well during the short time of the highest velocities. So the curves may possibly show some windtunnel-effect.

The trial-flights at Peenemünde deserve a few words. The trials were made by starts from the ground and by starts from planes. The observations were made by cameras in a distance of about 50 to 100 yards from the start,(one of these usually a slow-motion-camera) and by the usual measuring-base cinotheodolites. A few observers used stopwatches to check special questions such as the time delay in lighting the boosts, blowing off the boosts and so on. About the first thirty trials were made by us, the following by the personnel of Peenemünde with some assistance by us. The opinion that the designer ought to be held responsible for his product until he proves his theories, was hereby strengthened, especially as the time was short. A careful and responsible interpretation could only be made with a few of the approximately ninety test flights, Although the missile did not reach its service-height on account of well-known deficiencies mentioned below, we could be sure to meet requirements, especially with some improvements of the motor-rocket.

The chief theoretical difficulty of the starts from the ground was the exact adjustment of the boost's jets. This was overcome from the outset by a special appliance, but nevertheless, the men had to handle it carefully, as with every critical piece of work.

III. Motor-Rocket.

The most serious delay in developing the Butterfly was caused by the motor-rocket, which came late, in small quantities and not quite meeting requirements. Therefore, we wanted to design and build our own rocket according to our own ideas, which we were not allowed to do. Later we got a satisfactory design, which met our demands, by Dr. Schmidt of Walther. Fig. 4 shows the curves of momentum versus thrust for both designs. Schmidt had made a new regulation-device, and an uncooled burning-chamber. There remained only one greater question: Would the emptying of the tanks work under any service-condition? The fuel in the tanks should be conveyed under pressure of about 1 atmosphere through a flexible tube to the pumps which drove it to the burning-chamber under pressure of about 30 atmospheres. I remained afraid that on account of the free surfaces and the changing accelerations an increasing part of the fuel would be mixed up with air and hereby overthrow the balance. Tests were being made to clear the doubts.

Other devices were discussed to some length.

IV. Manufacture.

February 1943 I went to Prof. Wagner, starting with first computations on the Butterfly and with the job of getting a workable crew together, for I was absolutely alone. Some of the best men I got while searching myself, but the greater number of collaborators I got from the Flak about October 1943, mostly young men with little practical knowledge, who were drafted four years ago. The first designs I had made alone, which differed chiefly from the later-ones with respect to body-length as I still had to learn about the motor-rockets. Sweep-back, position of boosts, and process of starting was then conceived with approval by Prof. H. Wagner. This work was done without order by the RLW. The order was given about August 1943, after we submitted a technical description similar to this one.

The first test-flights from the plane and from the ground, but without motor-rocket, were made in May 44 in Peenemünde where all test-flights have been made. The interval was caused by learning, since the first design October 1943, how to manufacture wings according to our requirements. The first test-flights with a motor-rocket were made about August 1944.

The production manufacture ought to have started February 1945, reaching an output of about 3000 monthly in October 1945.

Rough figures of working hours for Butterfly are :

Body, wings and tail unit	about	80 h
Boosts	"	50 h
Motor-rocket with regulator	"	250 h
Electric apparatus	"	400 h
Total	about	780 h

The difficulties of manufacturing the motor-rocket were not yet overcome. The tank for acid had a length of about 30 in. and a diameter of about 13 in. In this tank a piston had to move with a clearance of about 0,012 in. The weight had to be small, as the whole weight of the empty motor-rocket was not to exceed about 5,7 gr/kg sec. We considered building a new missile at a weight of about 3 gr/kg sec. for the empty motor-rocket.

V. Formula for Explosive-Charge.

In addition to what I have told about the effect of the explosive, I want to add the results of trials made later on.

Using the following symbols :

C = weight of explosive in kg
e = distance from Boeing B-17 in m

we got the following formula :

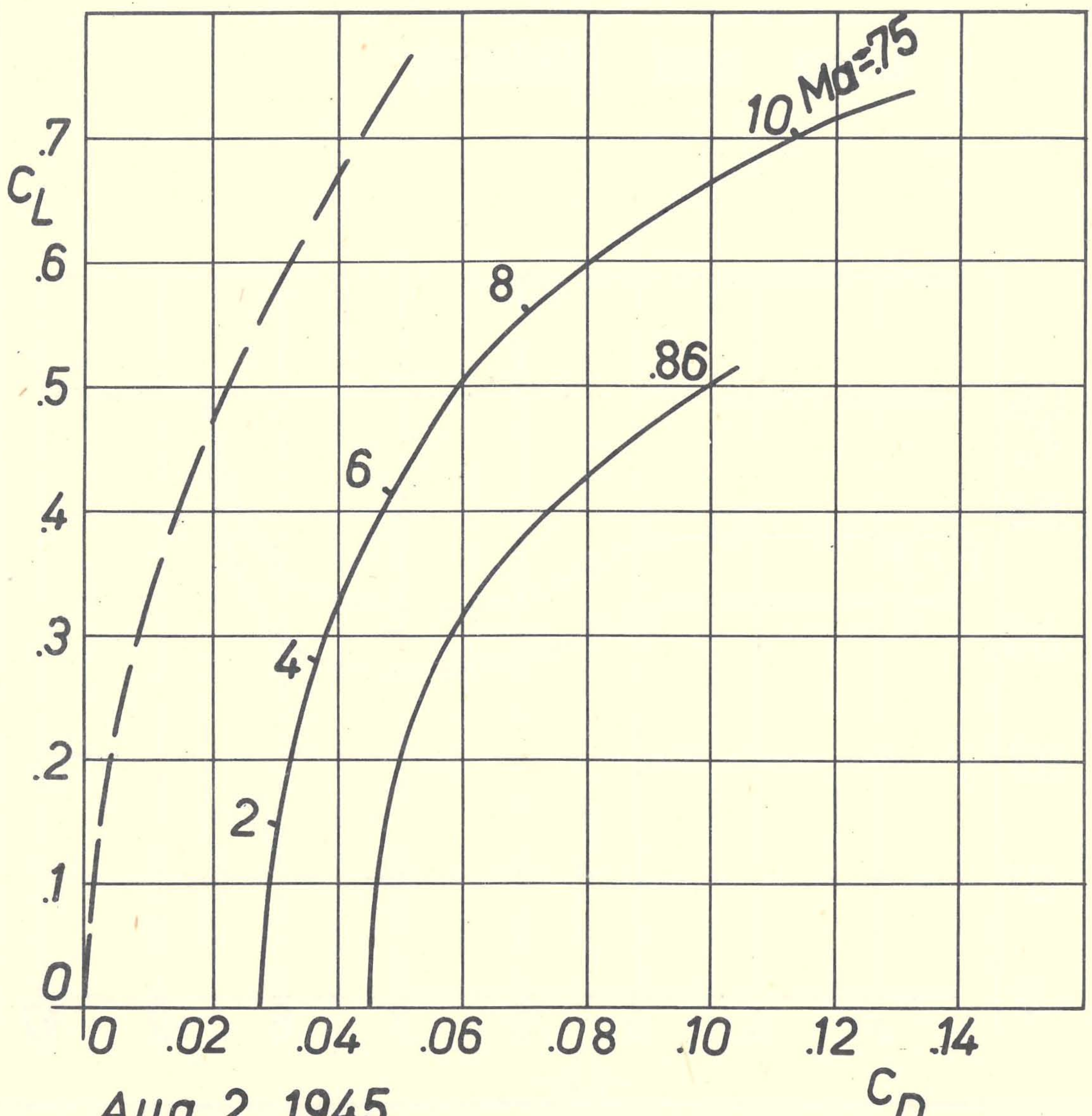
(1) $G = 0{,}033\ e^4 .\ (e-4)^{-1}$

if blowing against the unloaded side of wing beyond a distance greater than 6 m.

(2) $G = (0{,}33 - 0{,}002e) .\ e^3 .\ (e-2)^{-1}$

if blowing against the loaded side beyond a distance greater than 3 m.

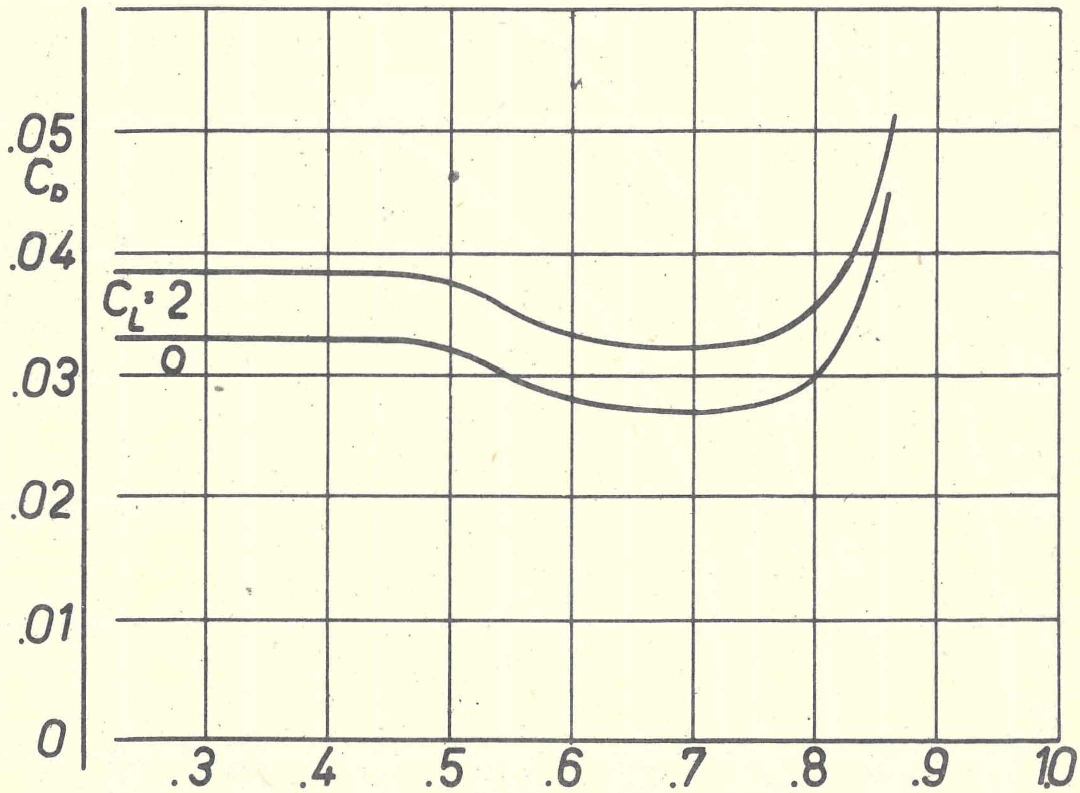
Butterfly Fig. 1
Characteristic curves

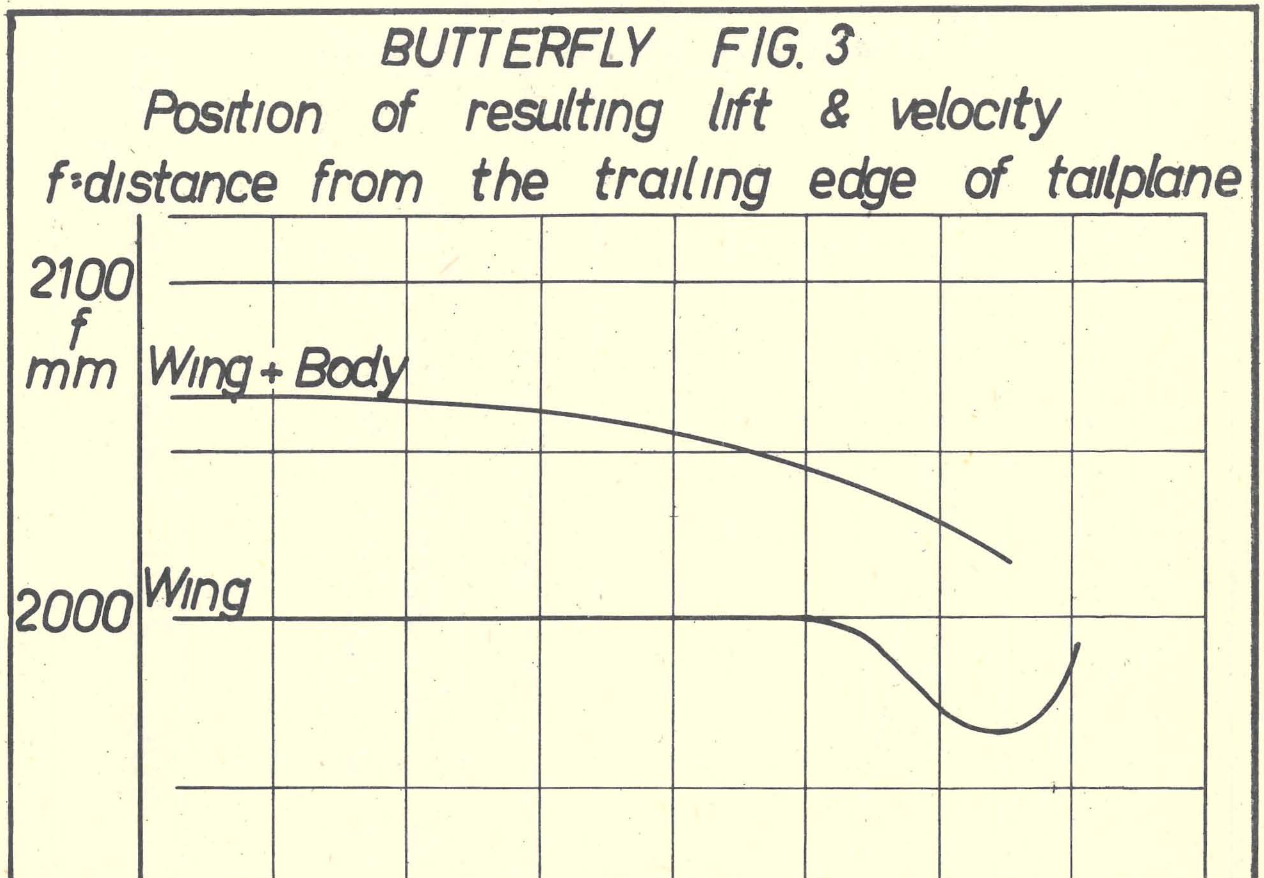


Aug. 2, 1945.

Butterfly Fig.- 2

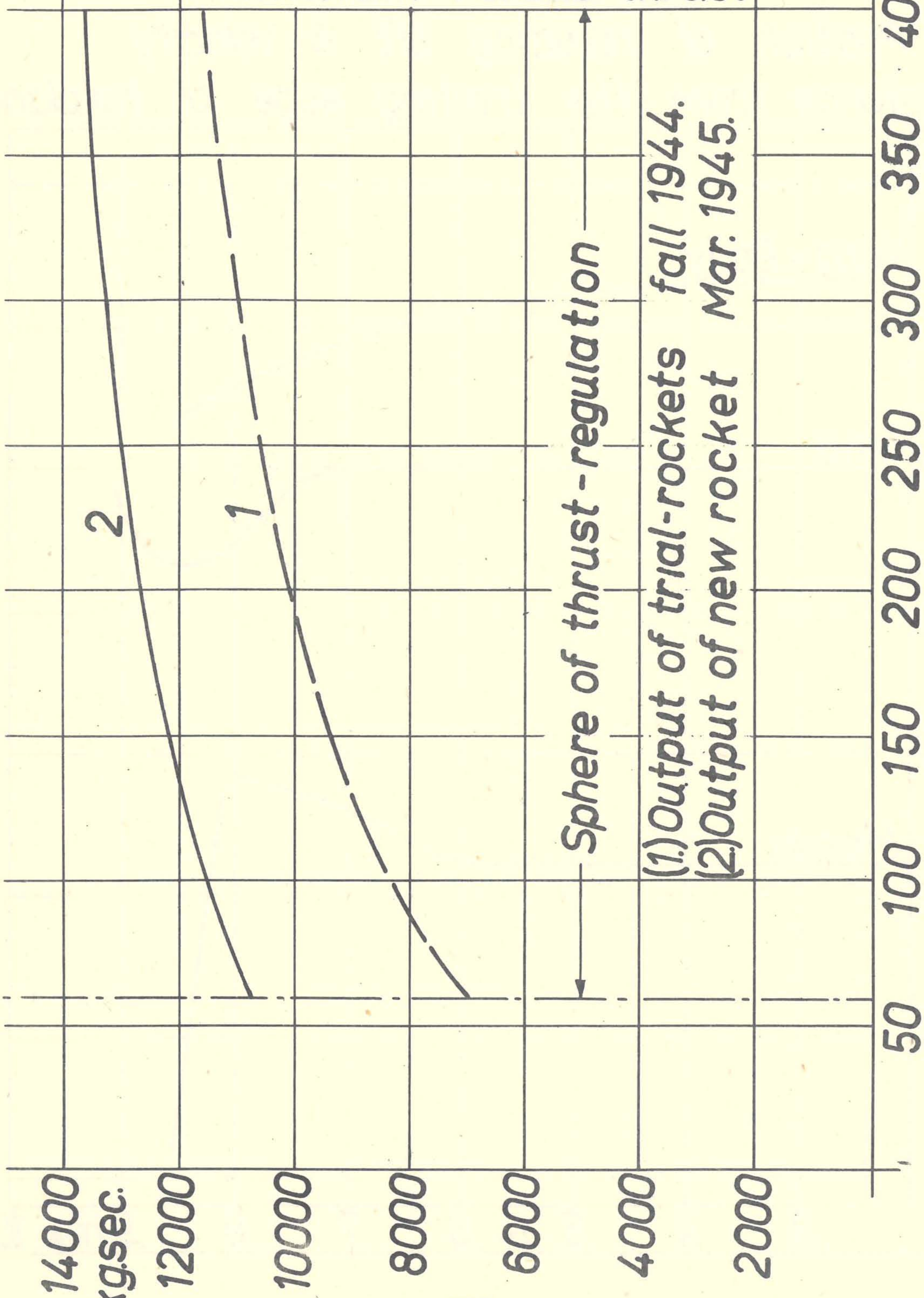
Drag and Velocity

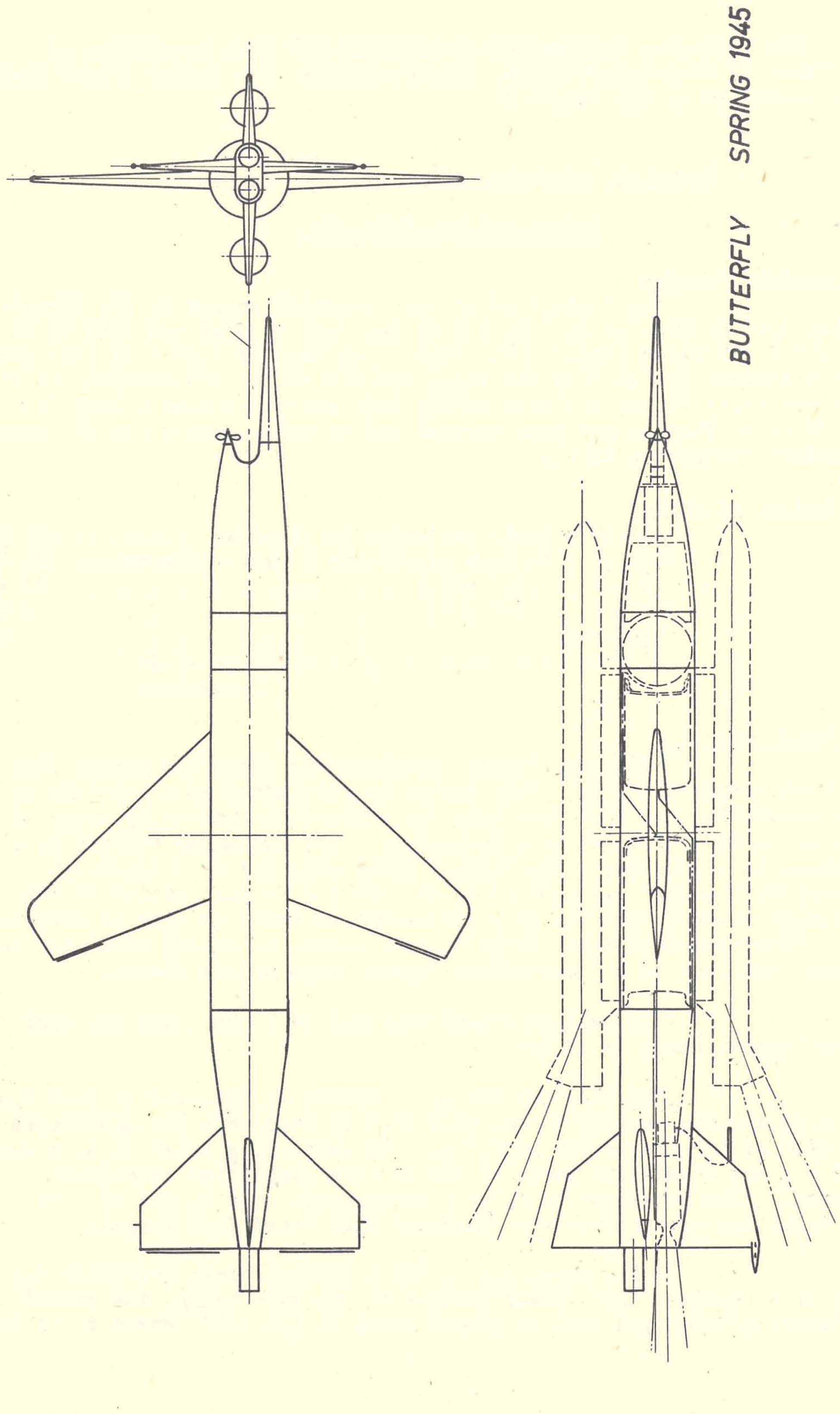



BUTTERFLY FIG. 3
Position of resulting lift & velocity
f=distance from the trailing edge of tailplane
2100
f
mm
Wing + Body
2000
Wing
1900
Missile
1800
.3
.4
.5
.6
.7
.8
.9
ma
10

Butterfly Fig. 4

Momentum versus thrust




BUTTERFLY SPRING 1945

The following information on Henschel G/M work by members of CIOS Team 367 from interviewing several people, the people interviewed being indicated in the report :

Notes on Interview with Dipl. Ing. HENRICI.

Schmetterling H.S. 117.

(1) Design History.

The concept of an air-to-ground weapon of the Schmetterling type originated in 1941 but design work on what was then known as the H.S.297 was sporadic until 1943. In July or August of that year the development was started seriously and the weapon was renamed H.S.117. The first trial flight was made in May 1944 and since then a total of from 80 to 90 flights had been carried out of which some 20 to 30 were Peenemünde Acceptance trials.

(2) Weight of Weapon.

All-up weight, excluding boost units	460 kg.
Wt. of structure, electronic & gyro equipment...	270 kg.
Primary rocket motor	75 kg.
Primary rocket fuel	75 kg.
Explosive	40 kg.
Boost rockets each 90 kg, of which 40 kg is propellant.....	

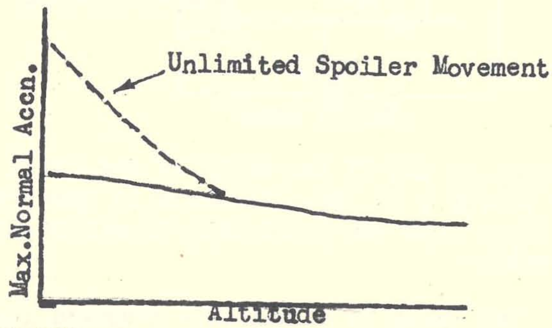
(3) Performance.

After the initial accelerating phase the weapon flies at a Mach number of 0.77. This latter is maintained at a constant value by regulating the fuel flow into the combustion chamber by means of a valve which is controlled by a Machmeter. The Machmeter construction is described in (5) below. The purpose underlying the requirement of constant Mach number was claimed to be purely a simplification of the aerodynamic control problem by eliminating the rapid changes of aerodynamic characteristics with change in Mach number which may otherwise be expected to occur in the operational speed range of the weapon.

The maximum height attained is 10 km., and the maximum horizontal range is 18 km.

The longitudinal acceleration at take-off is from 7.5 to 8.0 g, and the maximum normal acceleration available for manoeuvres over most of the trajectory is 7.5 g. In fact, 10 g could be attained but 7.5 g was considered adequate and its use simplified structural problems. The acceleration of 10 g corresponds to a C_L Max of 0.7; this value was measured in the Adlershof High Speed Wind Tunnel.

For a given C_L, or for a given average tailplane C_L, which at a constant Mach number amounts to the same thing, the normal acceleration developed will be proportional to $1/2.e.V^2$, where e. is the air density and V is the forward speed. This quantity varies considerably over the trajectory. In order to facilitate guiding from the ground it was considered desirable to eliminate as far as possible the variation of maximum normal acceleration with altitude. To this end a mechanism was introduced into the spoiler solenoid circuit which caused the spoiler movement to be reduced as the total head, which was measured by an ordinary pilot tube, increased. It may be noted that at a constant Mach number $1/2\ e.V^2$ is proportional to the total head. In this way, a curve of maximum acceleration against altitude was obtained something like that shown below.



(4) <u>Rocket Performance.</u>

(a) <u>Boost Rockets.</u>

The boost rockets each developed an impulse of 7400 kg. secs. within the limits -0, +400 kg, secs. Their burning time was 4.0 secs. guaranteed by the manufacturers only to within ± 0.5 secs. The nozzles were mounted on spherical joints which permitted their being aligned such that the direction of the thrust passed through the center of gravity of the missile-boost rocket combination. For the firings which had been made t to date, the adjustment was carried out individually for each rocket after it was fitted to the missile. The method was to use a Zeiss inclinometer which gave an angular accuracy of ± 3'.

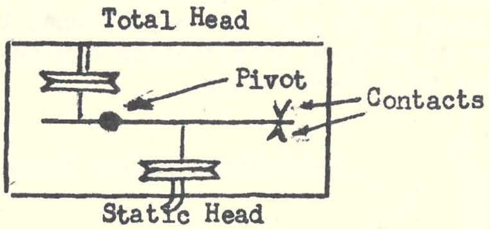
Henrici stated that no trimming troubles had been encountered due to interference between the boost rocket jet and the downwash at the tailplane. One question had been raised, however, concerning the effect of the boost rockets on the trim of the missile; this was whether toeing-out the jets would lead to the development of a force normal to the nozzle axis. Bench tests had been made but no off-axis forces were detected.

(b) <u>Primary Rocket.</u>

The impulse of the primary rocket was stated to be 12,500 kg. secs. with a burning time of 90 secs.

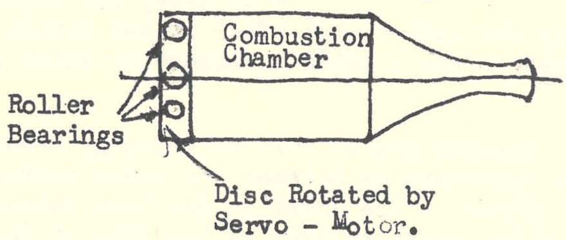
(5) <u>Machmeter & Motor Thrust Regulator.</u>

The Machmeter consists of two diaphragms, the one sensitive to static pressure and the other to total head. The diaphragms, or capsules, are connected to a lever such that at a Mach number of 0.77 the lever is in a neutral position with respect to two contacts. The contactd and lever form part of a servo motor control circuit and the direction of operation of the motor depends on whether the Mach number is greater or less than 0.77. The arrangement is shown diagramatically below.



It may be noted that at M=0.77 the ratio of the total to the static pressure is very nearly 1.5: the distances of the total pressure and static pressure links from the pivot may, therefore, be expected to be roughly in this ratio.

Two types of valves were proposed for regulating the fuel injection into the combustion chamber. The first was designed by BMW and consisted of a perforated plate which was pressed against pressure. The fuel flow was varied by rotating the plate. However, the method was found to be unsatisfactory and was superceded by a design evolved by Walther at Kiel. The principle was much the same, but instead of altering the area of the combustion chamber fuel entries by means of a flat plate, roller bearings operated by a rotatable disc were used. A sketch of the arrangement is given below.



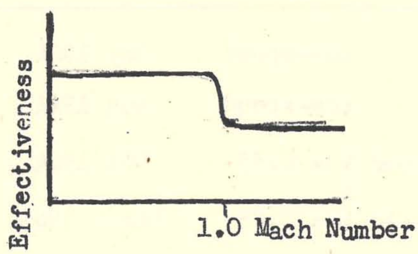
The time-lag in the complete system which included the Pilot static tube and lines, Machmeter, servo-motor, and fuel valve was such that the variation of Mach Number during flight never exceeded 0.03. The greatest lag was encountered in the servo-motor and this was designed such that at its initial maximum rate of operation it would move the fuel regulator through its complete range in 3 secs.

(6) Spoiler Control. (Wagner Rüder)

A considerable number of wind tunnel tests had been made to determine the characteristics of the Wagner rüder both at low and at high speeds. These tests showed that for the 12% thick aerofoil section used in Schmetterling the optimum width of spoiler was from 2.5% to 3% of the aerofoil chord. For greater wdiths the drag increased rapidly and for smaller widths the effectiveness of the control became small. It would appear that, in effect, the best arrangement is such that in its extreme positions the spoiler is just immersed in the aerofoil wake.

The method of operation was to apply a voltage to the actuating solenoids in the form of a square wave. Thus the spoilers were continuously oscillating between their extreme positions. Proportional control was obtained by varying the duration of successive semi-periods in each cycle so that the spoiler remained longer in one position than in the other. Maximum control in any direction was attained for $\frac{a-b}{a+b} = 0.95$, where a and b are the semi-periods of each cycle. This implies that in this condition the ratio of the times spent at each stationary position is 38:1.

Wind tunnel tests had shown the spoilers to suffer no sensible reduction of effectiveness up to a Mach number of 0.85. Furthermore, tests at supersonic speeds revealed that the spoilers were also effdctive in that range but that the effectiveness was only a little greater than one half than at low subsonic speeds. The type of curve found for the variation of effectiveness with Mach number was as follows:



(7) <u>Stability.</u>

Previous interrogations of personnel associated with the design of Schmetterling suggested that some troubles had been encountered in the early trial stages with aerodynamic instability. Henrici, on the other hand, asserted that no such difficulties had arisen; in fact, the aerodynamics of the missile had not at any time subsequent to the design, presented any serious problems.

The following approximate figures for the C.G. margins during flight were quoted :

No.	Condition	C.g. margin
1	Weapon with all liquid fuel, and boost rockets with all solid fuel	0.21
2	As (1) but with solid fuel burnt	0.16
3	As (2) but with boost rockets jettisoned	0.20
4.	As (3) but with all liquid fuel burnt	0.17

(8) Wind Tunnel Tests.

The following wind tunnel tests had been made on Schmetterling :

No.	Tunnel	Speed	Date	Model
1	D.V.L.	Low-speed	May 1944	1:2 Scale; wooden
2	D.V.L.	Low-speed	Aug 1944	1:2 Scale; wooden
3	D.V.L. High-speed	M = 0.85	Oct 1944	1:2 Scale; aluminium
4	D.V.L. High-speed	M = 0.85	March 1945	1:2 Scale; aluminium
5	A.V.L. GOTTINGEN	M = 0.9 & 1.2	---	----

Henrici asserted that the reports on tests 1to4 had been destroyed but that the results of the Göttingen tests might be available. These latter were carried out under the direction of Prof. Walchner of the A.V.A. and accordingly, he was interviewed. He stated that again the reports had been destroyed but that it might be possible to reconstruct them from the tunnel laboratory records which, he believed, were still in existence. Prof. Walchner agreed to try to find the laboratory books and, if they were available, to rewrite the reports. This would take some 10 days or so. A further visit to Göttingen is, therefore, proposed to investigate the progress of Walchner's work and to discuss with him tests made at A.V.A. on other projects. It is also intended to have a further discussion with Herr Henrici.

The following information relating to work on the development of components for HS-293 was obtained from Dr.Harold of Z.V.H. at Innerthan.

(1) Radar Homing Device for HS-293.

The radar homing device was to be mounted on the nose of an HS-293. The aerial system consisted of four separately fed dipoles, which were situated at opposite ends of the horizontal and vertical diameters of the nose. Each had a polar diagram which squinted sideways at an angle of about 40 degrees. The aerials were connected alternately to the receiver through a 4-way rotating switch. Signals from shipborne radar are received and smoothed in four separate circuits, and the outputs from the up/down and left/right aerials are fed differentially into the aileron and elevator control circuits. The resulting split polar diagram gives linear indications of target misalignment up to angles of 40 degrees on either side. The left/right control is fed in through the roll stabilising gyro. The latter has two ganged potentiometers on its outer ring which are fed with D.C. from the left and right receiver outputs. When no control is being applied and the missile is flying straight there is no voltage difference between the two sliders. If a gust disturbs the missile, then the voltages on the sliders change in opposite directions and the resulting difference is applied to the aileron servo motor. When a misalignment is recorded, a voltage difference between the sliders is set up and bank is applied until this voltage is again zero. A rate of turn is therefore produced which is proportional to the target misalignment and, apart from delays in the servo system, the missile turns so that the misalignment decreases with time exponentially. In the vertical plane the output voltage difference between the upper and lower dipoles is fed directly to the servo motor driving the elevators.

(2) Coincidence Pulse Fusing System.

The coincidence pulse system of fusing for the HS-239 was for use when the target and the missile were both observed with the Neptune R Gerät. Pulse coincidence by visual observation of the signals on the CRT indicator was too inaccurate and so an automatic method was used. The combined signal was strobed and passed through a delay network which gave a delay of one pulse width. The delayed and undelayed signals were then multiplied and the result was peak rectified. When the two pulses were in coincidence the output from the multiplication circuit was zero, the output changing sign as they passed through coincidence. This output was therefore connected to a balanced relay which sent out the fusing signal as it passed from one pole to the other.

(3) Proximity Fuse.

A.E.G. have developed an electronic proximity fuse which was said to be in mass production. It consisted of a unipole mounted on the nose of a missile, and tightly coupled to a small CW

Oscilator. A second oscilator was also incorporated which ran at a frequency of 800c/s less than that of the first. The beat frequency was obtained in a mixer. In the proximity of an aircraft or other large conducting body the frequency of the first oscilator was pulled by the change of aerial impedance and the beat frequency increased. The latter signal was passed through a 1000 c/s filter the output of which operated the fuse.

B. WASSERFALL.

I. General Description.

1. Specification.

The Wehrmacht laid down the requirement for a flak rocket to attack under the following conditions:-

a.	Maximum target height	...	20 kilometers.
b.	Minimum target height	...	5 kilometers
c.	Maximum target speed	...	250 meters/sec
d.	Desirable maximum range of engagement		50 kilometers.

In addition an accuracy and reliability such that other missile should bring down its target. As will be seen below, this specification was not met in all respects.

2. Description of Project..

Wasserfall - developed to meet the above requirements - was powered by a bi-fuel rocket motor which could be guided to the vicinity of its target by radio. It was understood that it should be fitted with a proximity fuse and a homing device, but they were not yet ready.

3. The General Details are as follows:-

All up weight	...	3850 kilograms.
Weight of Explosive	...	250 kilograms.

distributed to obtain maximum fragmentation with minimum excess metal :

Salbei (90% HNO_3 - 10% H_2SO_4)	...	1500 kilograms
Miscol (Organic fuel)	...	700 kilos.(app)
N_2 for pressurizing tanks (and antenna)		70 kilograms.
Tank pressure	...	25-27 atmosphere
Thrust of motor	...	7000 kilograms.
Impulse of motor		180, 000 kilogram/sec
Time of firing	...	45 seconds.
Starting upward acceleration	...	1 g.(approx.)
Speed after 6 seconds	...	70 m/sec.(approx)
Height after 6 seconds.	...	200 meters (approx)
Max.longitudinal acceleration	...	5 g.(approx)
Max. design lateral acceleration	...	12 g.
Center of gravity movement during flight		10 cm.(approx.)
Control surface angular rate	...	40°sec.
Control surface movement	...	20°

4. Present Status of Wasserfall.

About 50 Wasserfalls have been fired at Peenemünde for tests of the propulsion and guiding systems; no tests were made against an aircraft target. The tests appear to have been successful on the whole, although there was evidence that the stability margin on passing through the sonic region was small. No homing device or proximity fuse was tried.

II. Description of Wasserfall Control System.

1. General Description of Control System.

Wasserfall, like V-2, is fired vertically. No control other than the gyrostabilisation (see below) is applied until six seconds after firing when the missile has reached a height of about 600-ft and is travelling at 180-ft/sec. One second before this point, the missile appears in the field of view of the sighting instrument of the operator. After six seconds from release, the operator's joy-stick is moved according to a program computed by the "Einlenk gerät" (later described) and the operator manoevres the missile by means of a joy-stick which actuates the control surfaces on the projectile through a radio link so as always to keep the missile in the center of the field of view of the telescope. The program given by the computer is such that the missile, the observer and the target are brought into collinearity; when this occurs, the operator attempts to keep the target and the missile collinear. To assist this, it was intended to use a "t-Rechner" (described below) which determined the angle between the horizontal line lying in the yaw plane of the projectile and the horizontal projection of the line of sight. The axes of the control stick are, in effect, turned through this angle, enabling the operator to preserve the same direction of control for the same apparent directional error throughout the trajectory. In order to have available throughout the trajectory, the maximum design lateral acceleration despite the speed variation, the control surface movement ratio is continuously decreased along the trajectory on a time basis. This also has the effect of simplifying the control problem as the same effect for a given stick movement was preserved throughout the flight. It was proposed to do this in practice either by varying the amplitude of the control signals sent from the ground with time, or by varying the effects of given signals on the missile by apparatus on the missile.

In the development of the control system, a mechanical model and an electric simulator were used. The chief trouble encountered in the development of the control system was the very wide range of movement torques required, at the high Mach numbers, especially while in the transonic region the missile was almost unstable necessitating large rudder movement for control in a given direction. However, it was hoped to overcome this by aerodynamic re-design. In spite of the large variations in torques required, it was necessary to maintain the strict following of the control movements called for.

2. Method of Trajectory Control.

The weapon was, in the first instance, for use in daytime against bomber formations and a visual method of control was to be used. The set up on the ground consisted of the firing platform; a telescope for observing the target; a telescope for observing the missile, the observer, through this, being in control of the missile; a computor called the "Einlenk Gerät" and the Kehl transmitter. At the test site at Peenemünde these various positions were grouped together within a few meters of one another.

The missile was controlled so as to fly on a line of sight course with respect to the controlling observer and the target. The method of launching the Wasserfall, however, necessitated some increased complexity over the simple line of sight procedure. The missile was launched vertically and flew in this direction for six seconds up to a height of 200 meters. It was then controlled so that it approached the line of sight course as quickly and as stably as possible, taking into account the limited manouvrability of the missile. If the directions of the missile and target are defined in terms of azimuth and elevation, the method may be described as follows. Apart from parallax corrections, the observer's telescope started by looking vertically. After six seconds its azimuth was controlled so that it was the same as that of the aircraft viewing telescope. Its elevation was also controlled so that if the target elevation was γ and the observers telescope elevation was B the differential equation.

$$f(t)\,\ddot{\beta} + k(\dot{\gamma} - \dot{\beta}) + g(\gamma - \beta) = 0 \quad \cdots\cdots\cdots (1)$$

expressed the relation between them.

k is a calculated damping constant
f (t) is a function of time after launching such that

$$f(t) = \frac{12}{t-5} \quad t \text{ in secs.}$$

g is a function which is linear for small values of $\gamma - \beta$ but which becomes constant at larger values.

If the controlling observer kept the missile central on the cross wires in his field of view, then it flew on a course which approached the correct line of sight asymptotically and when it was actually on the line of sight be held it there as closely as possible. A difficulty arose since the control axes of the missile did not coincide with the control axes of the observer. The relative rotation of the two systems arose because the missile could be directed on to any azimuth, and since it could not roll about its own longitudinal axis, a roll with respect to space axes was produced. This effect was to be measured with a radio system which was called the "Taurechner" and will be described later. Since roll is to be determined, some form of polarization method was necessary, the 180 degrees ambiguity being resolved by a knowledge of the control applied. The component of roll with respect to the line of sight was then fed in to the control stick system, as for example by rotating the control stick pick-off column, so that the observers axes became those of the missile.

3. Control System.

According to Dr. Klein and Dr. Geissler, Wasserfall, at least in the earlier models, had three free gyros mounted so as to measure pitch, yaw and roll separately. Each had a double potentiometer pick-off on the outer ring wired as a bridge circuit, so that a movement of the outer ring with respect to the case unbalanced the bridge. The latter was fed with D.C. so that a D.C. output proportional to the misalignment was obtained from the pick-offs. This was fed into a ring modulator which produced a proportional 500c/s A.C. output. This was then amplified, rectified and fed to the rudder servos. There were four separate rudder servos which each drove a linked aerodynamic and jet rudder assembly. The servos used were the LGW oil type as used in the later models of V-2. A pure electrical servo of smaller size had been designed and was to replace the oil servo. The output from the pitch gyro came from the ring modulator as a balanced signal and this was fed to the two amplifier valves operating the two horizontal rudder servos. The output of these valves was so arranged that a balanced output worked the rudders in the same direction and so produced pitch. In the same manner a balanced output from the valves operating the vertical rudders moved them also in the same direction and gave yaw. The balanced roll output was fed to the centre points of the pitch and yaw outputs. This caused opposite motions of the horizontal and vertical rudders and produced roll. A potentiometer in the rudder servo provided a position signal which was fed back into the ring modulator inputs. For a given gyro misalignment and, therefore, the rudders took up a deflection given by

$$B = k$$

the motion of the rudders in taking up this deflection being damped by internal servo damping. The constant k was varied as a function of time by automatically altering the voltage applied to the gyro potentiometers. In this way stability was maintained as the speed varied. The actual values of k were determined both by wind tunnel measurements, and by trial flights.

4. Gyro System.

In the earlier models of Wasserfall, three mutually perpendicular gyros were used. These are standard aircraft directional indicator gyros, the misalignment of the missile with respect to either of the three axes displacing the slider of a potentiometer and thus unbalancing a D.C. bridge circuit. The unbalance output is converted into A.C. and amplified separately for each gyro. The output of the amplifiers is used to drive the rudder servo machines. The latter were originally the same as in V-2 but a later model of all electric construction was designed. The servo running at full speed turns through 90 degrees in 1.5 sec. but the linkage ratio to the rudder was not known. The rudder system in Wasserfall was the same as in V-2 except that all four pairs of air and jet rudders were linked instead of only two, and all were driven with the same type of servo motor.

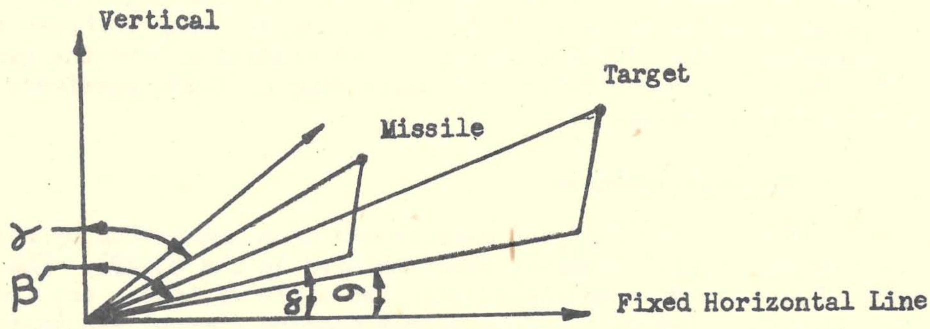
A complete gyro assembly was found in one shed and in another shed, several complete sets of "mischgeräte." These are very similar to the ones used in V-2, but some modification has occurred. One of the plug in units has an extension let into the case to house extra components. One of these units, in new condition, and the gyro assembly were sent back to R.A.E. A small dump of E-230 receivers had been destroyed by burning.

5. External Control.

Radio control of the missile was from the ground by means of the standard Kehl-Strassburg Gerät as used in the HS-293. The system used CW on 49.5 Mc/s modulated with two pairs of tones, one for L/R and one for U/D. The output from either command channel was an equal space to mark square wave when no command was being given. A command gave an increase or decrease in the space to mark ratio so that the mean D.C. level of the square wave was proportional to the amount of control stick motion. The command information was fed into the stabilising circuit in either of two ways. In one way the receiver output was fed through a relay amplifier called the "Itaregler" to a small D.C. motor which then rotated the gyro pick off at a speed proportional to the mean D.C. level of the command signal. When this method was used, therefore, the change of the direction of flight of the missile was proportional to the time integral of the amount of control stick motion away from the neutral position. In the second case the receiver output was rectified and the resulting D.C. was fed into the appropriate ring modulator in series with the gyro output. This produced a change of flight direction proportional to the control stick motion, and on returning the stick to its neutral position the missile flew again in the original direction. In this case the variation of the control constant k was done by varying the gain of the servo amplifiers. Apparently the rate method of control was preferred. The receiver aerial consisted of a dipole, each element of which was mounted on the trailing edge of an air rudder, on an insulating support.

6. The "Einlenk Gerät".

The object of this apparatus is to enable the rocket to be guided to the line of sight from the position approximately 200 meters vertically above the firing point obtained after the first seconds of flight. This must be done for various angles of the line of sight with the vertical without exceeding the maximum sustainable lateral acceleration. To do this a sighting telescope was kept continuously on the target and the azimuth and altitude angles measured continuously. A second telescope was moved with its azimuth and altitude definite functions of those of the first telescope, the functions being such that after a time the second telescope pointed at the target aircraft. The missile was steered by an operator looking through the second telescope who kept the missile in the center of his field of view until the target appeared in it; thereafter he steered the missile to keep it collinear with the target. Considering first for simplicity the impractical case where the operator is situated at the firing point of the missile, with the notation obvious from the diagram,



then the equation connecting the elevation and azimuth angles of the missile and target were, respectively:

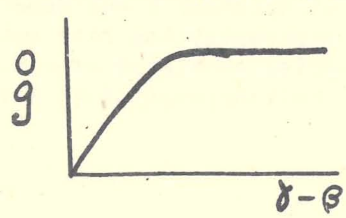
$$\ddot{\beta} F(t) + K(\ddot{\gamma} - \ddot{\beta}) + g\delta - \beta = 0$$

$$\sigma = \delta$$

where F(t) is a function of time from firing given by

$$F(t) = \frac{12}{t-5}$$

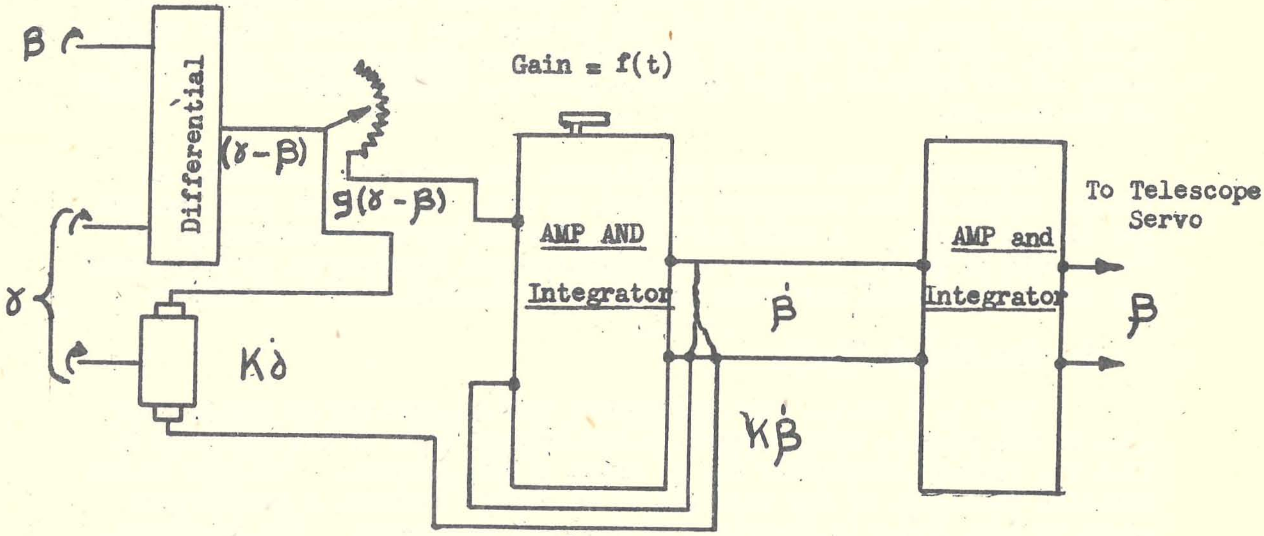
and g 0 is a function of (β-γ) which is approximately linear at first but then flattens off as indicated in the diagram.



The Einlenk Gerät was for solving the equation :-

$$\ddot{\beta}\, f(2) + k\,(\ddot{\gamma} - \ddot{\beta}) - g(\delta - \beta) = 0$$

The circuit was as follows:



The rotations of the two telescopes about their vertical axes were fed into a differential which turned the slider of a non-linear potentiometer wound so as to reproduce the function g. The output of this therefore gave g $(\delta - \beta)$. A D.C. generator was also mounted on the axis of the target telescope which produced a voltage corresponding to k$\dot{\delta}$. We have from the above equation

$$\ddot{\beta} = \frac{-k\ddot{\delta} + k\ddot{\beta} + g(\delta - \beta)}{f(t)}$$

$$\text{ie.} \quad \beta = \int_0^t \frac{-k\ddot{\gamma} - k\ddot{\beta} - g(\delta - \beta)}{} \, dt$$

The terms $-k\ddot{\gamma}$, g $(\gamma - b)$ with f (t) fed in as an overall amplitude control were integrated with feed back of $k\dot{\beta}$, and the resulting output was $\dot{\beta}$ This was again integrated and the output β was used to drive the observer's telescope servo. So it will be seen that the missile is steered so that it remains in the same vertical plane as the target whilst its elevation is related to that of the target by equation (1). Inspection of equation (1) shows that when it is large, F(t) will be small and when $\delta - \beta$ is small enough to be on the constant slope portion of the g curve, then $\gamma - \beta$ will asymptotically approach zero.

The relation, which [illegible] must cover widely differing target flight paths, took nine months work to produce by caulculating the various trajectories. In practice the observer is not situated at the firing point and when he is sufficiently far away to introduce serious errors in the above equations, another computer was to have been provided which calculated the azimuth and attitude required at the new telescope position in terms of the distance of the observer from the firing point and the range of the missile.

Depending upon initial conditions, the computer took up to 20 seconds after it had commenced control to bring the missile into the target line of sight. A model of this apparatus had been constructed at Peenamünde by Selvers using a straightforward integration circuits and the production model was being designed by "Kreisel Gerät" of Berlin.

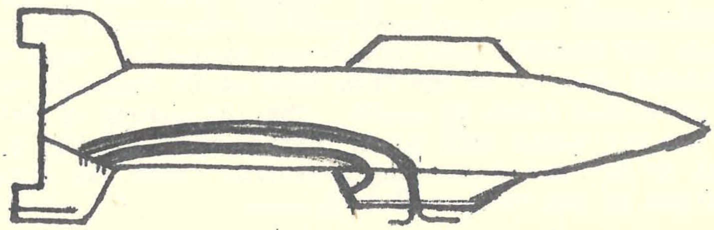
8. <u>The "Tau-Rechner"</u>

This is a device for determining the orientation of the control axes of the missile with respect to the control axes of the observer so that the correct directions can be given to the missile. We have little detailed knowledge of how this was to be done; however, a method proposed by Dr/. Lange is described in the next paragraph. The apparatus, which was under development by Telefunken, utilized a radio transmitter in the missile. The effective control zero of the joy-stick on the ground were rotated electrically so that left or right and up/down control axes in the missile.

This method, proposed by Dr. Lange but not actually constructed, was to follow the target with a scanning Wurtzburg beam and to have a responder in the missile. Since the polarisation of the Wurtzburg beam was rotating, the signal picked up by a dipole on the missile had a mod. sine modulation. The phase of this modulation with respect to the rotation of the Wurtz burg dipole gave the required angle of the roll, T, The signal was repeated back to the ground where it was received and the second harmonic component was picked out. This was used to lock an oscillator of frequency equal to the rotation frequency of the dipole, and the output of this was compared, in a phase sensitive rectifier, with a sine wave generated on the dipole shaft itself. To avoid ambiguity it was necessary that a continuous measurement of T be made.

9. <u>Test Model of Wasserfall.</u>

An aluminium model was found in a pond near the Kaliwerke which was approximately one quarter full size. This had two dipoles of variable length mounted along the edges of one wing.



The best explanation for this model is that it was used for impedance and polar diagram measurements. It was suggested by Dr. Reis that transverse unipoles were to be used. Several apparently unmodified E-230 receivers were found amongst the rather badly looted laboratory gear, indicating that this receiver was to be used for the radio control.

III. The Homing Device (Missina Gerät)

Homing devices are described elsewhere in detail but for Wasserfall it was intended to use an infra-red device which began to operate 3 or 4 kilometers from the target. Because of the small field of view of the "eye" (± 3 degrees on the preferred model) it was necessary to point the eye at the target at the beginning of the operating region. This was done by Krücke A or B described below. The radiation from the target was modulated by a disc on which strips were blacked out so as to produce a frequency modulated square wave, the frequency excursion of which was a linear function of the angular target misalignment. The polar angle of the target was determined from the phase of the square wave. The square wave was limited and passed through a discriminater circuit the output from which was a sine wave whose amplitude was proportional to the radial error of the target and the phase to its azimuth error. It was proposed to stabilize the eye so that it maintained a constant direction in space. In this way a collision course should be obtained.

The following information was obtained on the "Messina Gerät", by interviewing Dr. Weiss. Dr. Weiss worked on the design of the infra-red homing eye called "Messina." The first idea was to use an eye which was mounted rigidly along the axis of the projectile and which gave proportional indication of target misalignment off this axis. This method sufferred from two disadvantages. Firstly that the pitch and yaw of the missile gave false indications of the angle between the tangent to the flight path and the direction of the target, and secondly that if a predicted collision course was being flown, the direction of the target might make a large angle with the axis of the eye, thus necessitating a large field of view and consequently a small range sensitivity. It was therefore decided to use an eye mounted on a stabilized platform which was so steered during the initial ground control of the missile, that the eye looked always along the line of sight, and therefore at the target. This was to be done by means of the "Krücke Gerät" for which two forms had been suggested. In one scheme, the eye was rotated on the platform by signals from a backward looking receiver which D/Fed a ground transmitter, and in the other scheme, the eye was turned by signals from the ground by an amount which was determined from a measurement of the rocket direction. In either case, when the missile came within the operating range of the eye, control was handed over to it and from then on it remained with its axis looking in a direction fixed in space. The inaccuracy of the Krücke Gerät in pointing the eye would lead to an initial misalignment E of the target with respect to the eye axis being measured. This was used to produce an angular motion of the rudders β such that

$$\beta = f\ (E)$$

The ideal trajectory would be one for which $E = 0$ this leading, in the case of a straight flying target, to a straight line collision course, and in the case of a non-linear target motion to a sideways acceleration of the missile which was not greater than the sideways acceleration of the target. In order to produce a stable homing trajectory the function $f\ (E)$ had to contain other time derivatives of E but its form had not been determined.

The homing device consisted of a mirror with a rotating shutter at the focus. The radiation passing through the shutter was diffused on to the surface of an Elac infra-red cell, the output of which was amplified. Weiss devised a shutter with strips which gave square wave chopping of the radiation, the chopping being at constant frequency for an image on the axis, but having an increasing frequency modulation deviation for a source at an increasing angular misalignments. The output of the amplifier was therefore connected to a frequency discriminator which gave a sine-wave output whose amplitude was proportional to the misalingment and whose phase, on comparison with a reference commutator gave the phase of this misalignment with respect to the eye axes. The use of frequency modulation was said to give the direction of the brightest spot in a distributed target, but this does not appear to be true if normal amplitude limiting is carried out before passing the signal into the discriminator. This method does however seem to lead to a very simple circuit for sorting out proportional misalignment. The beam width necessary for a homing device used in this manner was determined by the accuracy of the Krücke Gerät and also by how far the manoevrability of the missile could keep $E = 0$. Beam widths actually used were from 6 degrees to 12 degrees. Weiss said he had a scheme for using a much narrower beam but he refused to discuss it. It is presumed that he was considering a locked follow eye with initial scanning in order to find the target.

IV. Wasserfall Simulator (Prof. Fischel and Dr. Schedling)

1. General Description of Simulator.

Two simulators were built at Ainring to study problems relating to the control of flak rockets. Both were three dimensional models, the first being of a qualitative nature and the second quantitative. The qualitative model had been completed and experimental work done with it, but it has now been dismantled. Parts for the more accurate and detailed model are about 50% complete but it is stated that six months work is still required.

With the first model work was done on the psychological aspect of the control of the missile by an observer. For example experiments were made to see if control by two observers, one for up/down and one for left/right gave better results than with one man who did both. It was also used for training controllers.

With the second model it was intended to carry out a much more detailed study of the control of particular missiles. The aerodynamic equations were taken into account so that the movement of the missile axes with respect to the observer as well as the motion of its center of gravity could be determined. They could therefore make experiments to find the best values of the constants in the rudder control equation, and also to determine whether the control stick should give position or rate control or a combination of both. It was also possible, by calculating the angle of incidence of the wings to observe what lateral accelerations were called for, and to see whether these exceeded the maximum permissible. The model was originally for Wasserfall, but modifications for use with Enzian and Rheintochter had also been worked out.

2. First Model.

The older model occupied a space of 10m x 3m x 3m. the linear scale being 1:5000. The target was represented by a small sphere which was supported by a string passing over a motor driven drum so that it could be raised or lowered at a speed which was proportional to the input to the motor. This drum was mounted on a trolley which ran on a horizontal rail. This rail was itself mounted on trolleys which ran along the upper longitudinal members of the framework enclosing the experimental space. The trolleys were driven by motors at speeds proportional to the input voltages so that the three Cartesian components of the target velocity were determined by three motor input voltages.

The rocket was represented by another sphere which could also be moved with respect to three perpendicular axes by means of a string and pulley system mounted on trolleys. The arrangement used in this case was a horizontal string passing over pulleys which were mounted on trolleys running on vertical rails. The latter were carried on trolleys running along the upper longitudinal members. This arrangement allowed the rocket to pass on both sides of the target without any of the members fouling each other. A schematic diagram of the movement is shown in fig. 1.

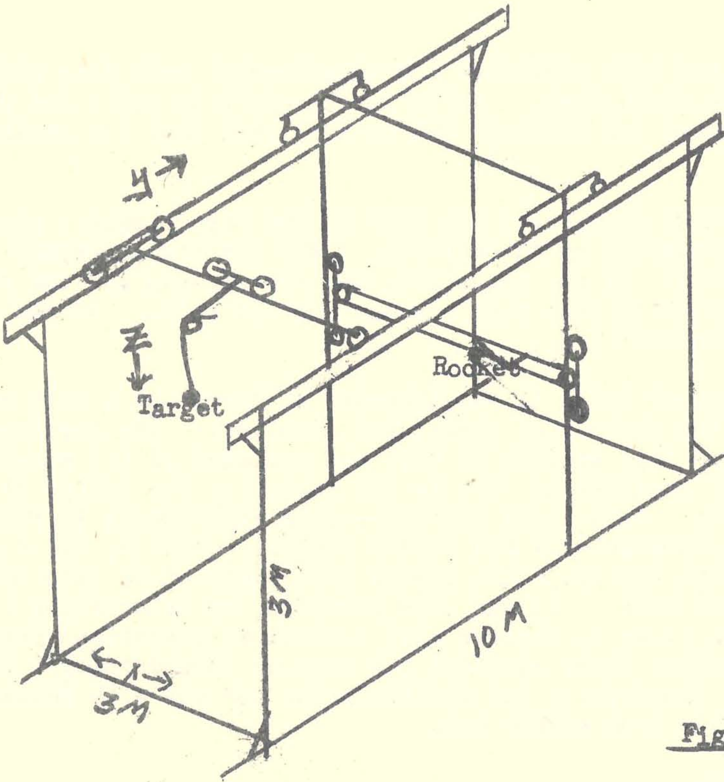


Fig.1.

The movement of the target was controlled by a man with a control stick mounted on axes as shown in fig. 2a. The direction of the stick can be defined in terms of the angles γ and σ in the coordinate system shown in fig 2b. It is seen that the outputs of the two potentiometers on the stick axes were proportional to these angles.

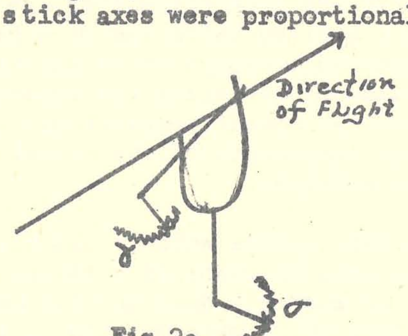


Fig 2a.

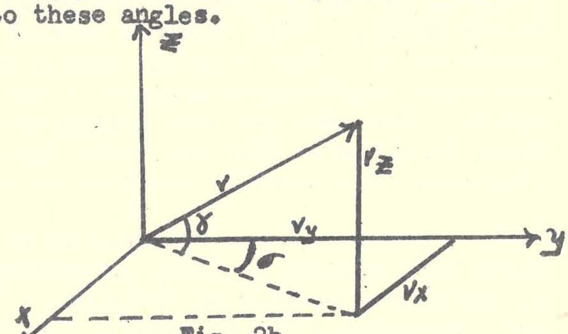


Fig. 2b.

The target was made to fly in the same direction as that of the control stick. If the target speed is v then the trolley speeds were made equal to v_x v_y and v_z where

$$v_x = v \sin\sigma \cos\gamma$$

$$v_y = v \cos\sigma \cos\gamma$$

$$v_z = v \sin \gamma$$

The value of v was chosen to suit a particular target aircraft. It remained constant in horizontal flight but it was increased or decreased proportionally if the aircraft dived or climbed. To allow for the fact that the aircraft has a certain maximum rate of turn, the values of γ and σ were not taken directly from the control stick axes but an intermediate circuit was used as shown in fig.3.

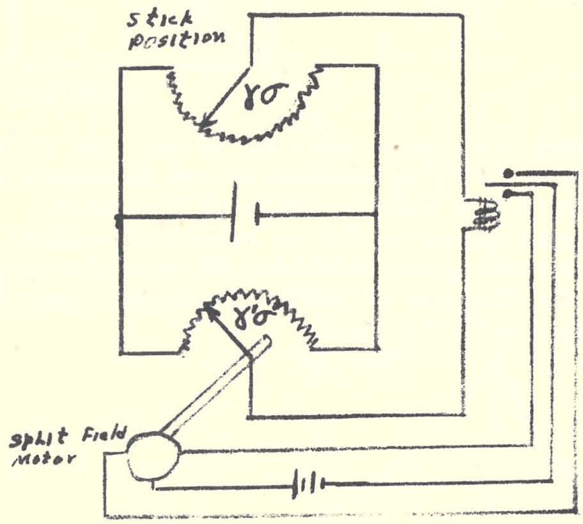


Fig. 3.

A second potentiometer was connected in parallel with the stick potentiometer which was driven by a motor and relay circuit. For values of $\frac{d\gamma}{dt}$ and $\frac{d\sigma}{dt}$ which were less than the speed of the motor the second potentiometer followed the movement of the first exactly, but when these were exceeded it lagged behind. The speed of the motor was made to correspond to the maximum rate of turn of the aircraft, so that during the control of the latter, this rate of turn was not exceeded.

The missile was controlled by means of a stick mounted on horizontal axes as shown in fig.4a. In this case the direction of the stick was defined in terms of the angles ϕ and X as shown in the fig. 4b. As in the case of the target, the missile was made to fly in the direction of the control stick by picking off from the stick axes the values of these angles, and feeding the outputs into a calculator which gave outputs to the missile driving motors proportional to the velocity components v_x, v_y and v_z, where

$$v_x = v \sin X$$
$$v_y = v \operatorname{cox} X \sin \phi$$

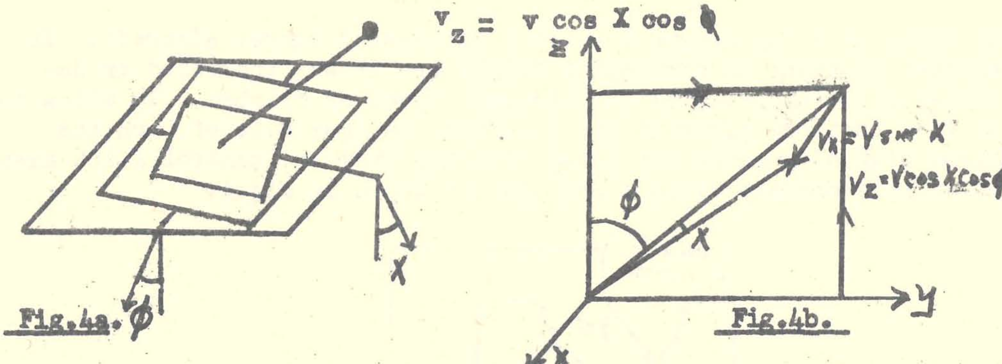


Fig.4a. Fig.4b.

A different set of control stick axes was used in the case of the missile since in the beginning it flies vertically and therefore if the δ, σ system were used, σ would be indeterminate at the start. The velocity was varied in the same manner as for an actual operation. Three different functions representing the variation of velocity with time were available depending on the flatness or otherwise of the trajectory. These are shown diagrammatically in fig.5.

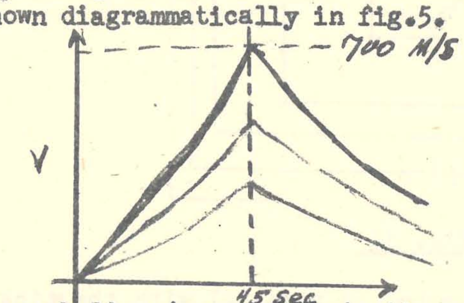


Fig.5.

The initial parabolic rise represents the uniformincrease of acceleration from the launching point up to the point of jet extinction. The latter occurred after 45-secs. From then on the velocity decreased owing to drag.

A potentiometer and motor system was used to limit the rate of turn of the missile as in the case of the target.

The calculation in the velocity component computer was done mechanically by means of cams. In the target calculator δ was fed in as a shaft rotation to a two-dimensional sine cam the output of which gave the vertical component of the velocity. It was also fed to two three-dimensional cams, one for cosine/sine for the x component and one sine/sine for the y component. The angle σ was fed to these as a translational movement. The overall magnitude of the output of each cam was varied as a function of δ by means of a lever system. A similar mechanical system was used for the missile calculator.

The three-dimensional cams were made on a drilling machine with accurate depth gauging and with a good dividing head. The tool used had a tip which was part of a sphere of curvature slightly less than the maximum concave curvature of the cam surface. In this way, from a cylindrical aluminium blank, a rough cam was prepared which had over its surface a system of dents representing true points on the required surface. The rest of the metal was filed off by hand and the surface was then polished and hardened by anodising. The accuracy was said to be 0.3%.

3. Second Model.

The new model was constructed on the same linear scale as the first but its height was increased to 5m to correspond to an actual ceiling of 25km. The target was controlled in exactly the same manner as in the old model. The missile control system consisted of the following separate items :

a. The control stick.

This was mounted on a system of axes similar to those shown in fig.4a. The angular movements with respect to these axes were called ϕ_k and χ_k.

b. The Rudder-Angle Calculator

The equation governing the motion of the rudders can be written as :

$$\eta = e_o \phi_k + e_{-1} \int \phi_k \, dt - a_o \phi_A + e_1 \dot{\phi}_k + \text{etc}$$

where

η is the angle of one pair of rudders on the missile.

e_o is a factor, variable with time according to a predertermined programme, expressing the gearings of the position control of the stick.

e_{-1} is a factor, also variable with time, expressing the gearings of the rate control of the stick.

e_1 is a similar factor for any integral control which may be necessary.

ϕ_A is the component of the direction of the longitudinal axis of the missile.

a_o expresses the gearings of the self-stabilizing linkage inside the missile itself.

A similar equation holds good for the motion of the rudders in the plane at right angles. In this simulator, the rotation of the missile control axes with respect to the observers axes was taken into account so that there was actually a linkage between the two equations. It was assumed that the aerodynmaic linkage between the two control was negligible.

The rudder angle calculator took ϕ_k directly from the control stick. The factors $e_{-1} \int \phi_k \, dt$ and $a_o \phi_A$ were obtained from a gyro system similar to that used in the actual missile. (See below).

c. The Moment Calculator.

The equation representing the rotation of the missile in the plane can be written as :

$$O \ddot{\phi}_A + D \dot{\phi}_A + C(\phi_A - \phi_B) + \frac{R \zeta}{\cos X_A} = 0$$

where:-

O is the moment of inertia of the missile, for this plane.
D is the aerodynamic damping.
C is the rate of change of pitching moment with incidence.
R is the moment produced by the rudder for unit rudder angle.
ϕ_B is the component of the direction of the trajectory.

A similar equation holds good for the relation between X_A and X_B.

It was found that the effect of the first two terms in the above equation was so small, on the trajectory as a whole, that they could be neglected in the calculation. In this calculator, therefore, the value of ζ was taken from the rudder angle calculator, ϕ_B was fed in from a unit further along in the chain, and a value of ϕ_A was therefore obtained. X_A was obtained similarly.

d. <u>The Gyro Unit.</u>

The gyro unit consisted of 2 standard Wasserfall free gyros mounted on a table supported on horizontal gimbals. The pick-offs were the usual double potentiometers, the stators of which were rotated by motors at speeds proportional to the control stick angles. The table was tilted through angles ϕ_A and X_A so that the output of the pick-offs was

$$e_{-1} \phi_k \, dt - a_o \phi_A \qquad \text{and} \qquad e_{-1} X_k \, dt - a_o X_A.$$

These were fed back into the rudder angle calculator as indicated above. In this way the inaccuracy of the gyro was taken into account.

e. <u>The Translational Motion Calculator.</u>

The equation expressing the sideways motion of the missile can be written as :

$$A\dot{\phi}_B = n' (\phi_A - \phi_B) - \frac{\sin \phi_B}{\cos X_B}$$

where:- $$n' = \frac{S}{G} + \frac{dc_a}{d\alpha} q \frac{F}{G}$$

S is the drive of the jet
G is the weight of the missile
c_a is the lift coefficient
α is the incidence angle
q. is the static pressure at the wings
F is the effective lift area of the wings.

The terms in the equation are non-dimensional expressions for the aerodynamic damping force, the side forces due to jet and lift, and the sideways component of gravity.

A similar equation holds good for the X components.
In this calculation ϕ_A and X_A were fed in from the moments calculator and ϕ_B and ϕ_B were obtained. These were fed back into the moments calculator as described above.

f. <u>The Trajectory Calculator.</u>

Since the direction of the trajectory was known at any instant in terms of the angles ϕ_B and X_B the dummy missile was then moved with component velocities given by

$$v_x = v \sin X_B$$
$$v_y' = v \cos X_B \sin \phi_B$$
$$v_z = v \cos X_B \cos \phi_B$$

by means of a calculator similar to the one used in the old simulator. The velocity v was obtained by calculating

$$v = \int \frac{S}{G} dt - \int G \cos X_B \cos \phi_B \, dt.$$

g. <u>The Incidence Calculator.</u>

The angle of incidence was calculated from the equation :-

$$\alpha^2 = (\phi_A - \phi_B)^2 \cos^2 X_A + (X_A - X_B)^2.$$

The value of α obtained was displayed and recorded so that the acceleration of the missile in a sidewards direction could be observed, and it could therefore be determined if the maximum permissible was exceeded during any particular run.

h. <u>The "Tau" Calculator.</u>

As in the case of the actual operation, it is necessary to take into account the apparent rotation of the rudder axes with respect to the axes of the observer so that, for example, the forward movement of the control stick really does give a downwards movement of the missile with respect to the observer. This was done by feeding back ϕ_A and X_A into the rudder calculator. The apparent angle of rotation of the missile axes is given by

$$\tau = X_A \sin \phi_A$$

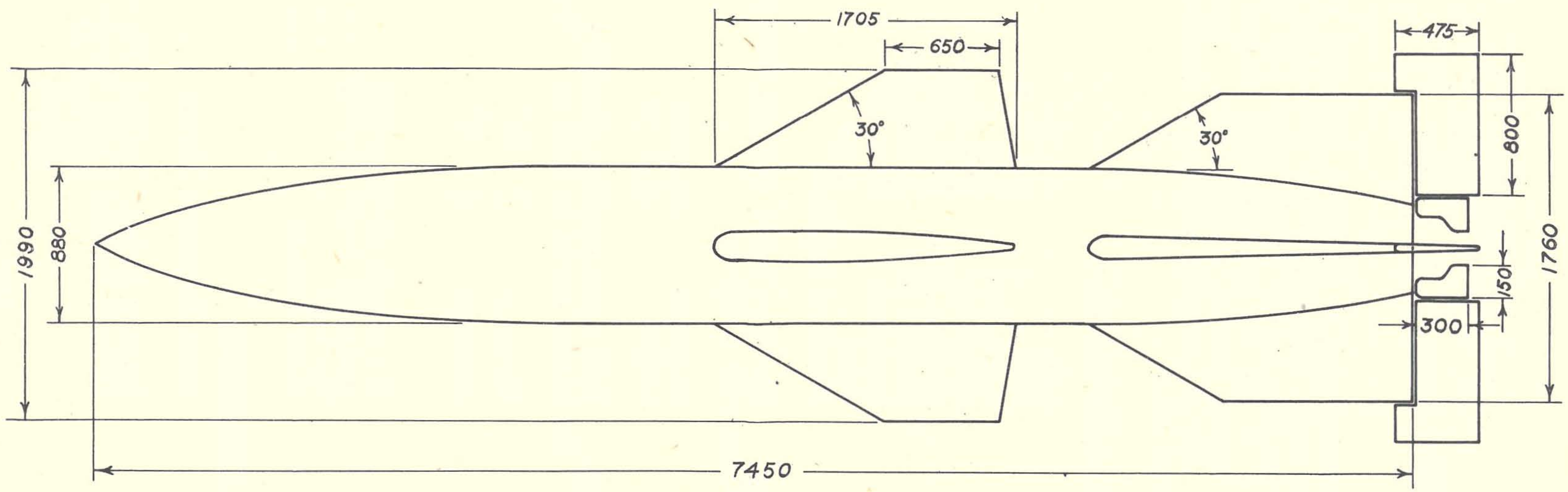
and so the new rudder angles are given by η' and ζ' where

$$\eta' = \eta \cos (X_A \sin \phi_A) + \zeta \sin (X_A \sin \phi_A)$$
$$\zeta' = \zeta \cos (X_A \sin \phi_A) - \sin (X_A \sin \phi_A)$$

i. <u>The Operational Display.</u>

In order to observe how closely the controller was able to keep the missile flying on a line of sight course, the actual positions of the missile and target trolley mechanisms were fed into two separate calculators which worked out the actual aximuth and elevation of both missile and target. The two results were displayed as spots of light on a screen, and recordings and measurements could then be made.

WASSERFALL



Note: All dimensions are in millimeters.

C. ENZIAN

I. ENZIAN I, II, III & IV.

1. Design.

The design was started in November 1943, and the construction of the first full scale model of Enzian I was started in January 1944. The first trial flight was made in May 1944; in all, 38 flights were made on Enzian I. Enzian I, II and III had a Walther bi-fuel turbo-rocket motor and Enzian IV had a Konrad bi-fuel rocket motor. Apart from this, the four types differed only slightly in structural design; the aerodynamic shape was the same for all.

2. Constructional Dimensions.

a. Wings.

Span	4 m
Area	4.9 sq m
Chord Root	1.25 m
Chord Tip	NACA 0020
Section Root	NACA 0010
Section Tip	30 degrees.
Sweepback	~~None~~ 30°
Twist	none
Mid-Wing Position	

b. Fuselage. Circular cross section with parallel center portion to which the wings were fixed :

Diameter	-0.88 m
Length	-3.9 m

c. Controls. Full span parallel elevons: Flat sided with about 40% balance. The elevon chord is 0.26 m. The angular ranges are :

Elevator	$\pm$ 10°
Ailerons	$\pm$ 5°

d. Weight

All weight at take-off, excluding boost rockets ...	1500 kg.
War head	500 kg.(Orig.450 kg)
Boost Rockets ...	420 kg.

e. Motion Performance

(1) Boost Rockets - Thrust ... 1500 kg. each.

(2) Primary Rocket- (Konrad Rocket)

Initial Thrust	2000 kg
Final Thrust	1000 kg
Duration of	½ sec
Impulse	110,000 kg secs.

3. Technical Details.

a. Launching.

The missile is launched from rails 6.8 m long; both the primary four-boost rockets are in operation during launch. The boost rockets are jettisoned after 4 seconds. The speed on leaving the rails is 24 m/s, and in order to guard against a stall, control is not applied until the flying speed reaches about 55 m/s (i.e. about 085). In practice this condition is met by giving control signals only after the first 5 seconds of flight.

b. Performance.

The weapon was designed to fly at a Mach number of 0.9. The estimated maximum height attained by a vertical launch was 16,000 m but with the Walther power plant only 7,000 m is attained.

The maximum normal normal acceleration over the middle part of the trajectory is 80 g. at a height of 7,000 m and a Mach number of 0.9. This corresponds to a C_L of about 0.8 according to Wurster. Wind tunnel tests suggested that the C_L max at mach 0.9 would be in the vicinity of 1.0; the C_L max at low speed was found to be 1.2. Even with the large sweepback used, the drop of only 0.2 m C_L max between mach 0 and mach 0.9 seems to be improbably small. At mach 0.9 the minimum turning radius of curvature was quoted as 250 m at ground level corresponding to a centrifugal acceleration of about 4.0 g and a bank angle of about 75 degrees.

c. Stability.

The C.G. max given at zero thrust was quoted as being 0.35 C, varying only slightly with Mach number. This was considered adequate in view of the large value of mach contributed by the wings. It was stated that the presence of this jet made an appreciable contribution in static stability. The lateral stability was chosen such that it just borders the spiral instability boundary. The value of n was 0.04.

d. Drag.

The low-speed drag coefficient was about 0.025. The critical Mach number was in the region of 0.86 but between M = 0.86 and M = 0.9 the Co rise was gradual.

e. Fuselage Shape.

Two advantages were claimed for the low fineness ratio fuselage. First, it allowed the use of spherical fuel tanks which were the most favorable shape for strength to weight ratio; secondly, the low fuselage length tended to reduce the destablishing effect on M_W and N_V.

The parallel-sided centersection was introduced to facilitate production. Wurster maintained that it also helped to reduce wing-body interference at high speed by virtue of the smaller excess and pressure velocity gradients in the neighborhood of the wing, as compared with a fuselage having a continuously curved profile. This latter is a questionable point, particularly for a low fineness ratio body since pressure breaks will be introduced at the nose-center section junction which may lead to the development of shock waves at high speeds.

f. Controls.

Wind tunnel tests showed that the plain, set-back hugh control in conjunction with wing sweepback as used on Enzian retained its effectiveness up to speeds of the order of Mach = 0.9.

A rough estimate suggested that at Mach = 0.9, the maximum torque required to deflect the elevators 10° would be 2.5 kg m and a further 2.9 kg m would be necessary to deflect the ailerons 5 degrees; i.e., one flap elevon would be at 15 degrees and the other at 5 degrees. The required rate of elevon operation was 10 degrees in 0.3 seconds. The Siemans servo motor used in existing models gave a maximum torque of 18 kg/m and delivered a power of 7.5 kg m/sec. It was hoped to replace this motor by an Askania or a further Siemans design which was much smaller and was capable of a maximum torque of 5 kg/m.

g. Production.

It was estimated that the total production time would be 450 man hours. Of this the engine would take 110 man hours to make. Provision was to have been made for an output of 10,000 per month.

II. ENZIAN V.

Enzian V appeared to be a private development of Messerschmitts. It was to be a supersonic missile capable of combating jet-propelled bombers and was in the preliminary design stage.

1. Description of Missile and General Dimensions.

Enzian V was designed to fly at a Mach number of 1.6 to 2.0. It had four separate wings placed symetrically around the fuselage. The body was similar to the other Enzian designs, but had an ogival nose similar in shape to the A4 nose of 7 C.E.W. The power plant was a Konrad design identical with that proposed for Enzian IV except that a higher combustion chamber pressure was used which lead to an initial thrust of 2500 kg and a final thrust of 1500 kg; the same amount of fuel was carried and the same specific impulse developed as in the Enzian IV so that the endurance would be correspondingly less.

The controls which were fitted to all four wings consisted of plain trailing edge flaps; one pair were operated as elevons and other pair as pure rudders. There was no fin.

The roll stabilization system was identical with Enzian IV comprising a free and a rate gyroscope.

a. Wings: Span - 2 m
Chord Root - 1.25 m
Chord Tip - 0.65 m
Area - 5.0 sq. m (four wings)
Sweepback - 55.0 degrees
Section symmetrical bi-corvex
Thickness - chord ratio root 7%
" " tip 4%

b. Fuselage: Length - nearly 6 m.
Max Diameter 0.88 m.

c. Weight: All of weight at launching, excluding boost rockets 1250 kg.
Warhead ... ... 250 kg.

d. Controls: Full-span, parallel-sided. The ratio of control chord to tip chord was 30%. Angular range :

Elvators and rudders... 5°
Ailerons ... 3°

The control areas were chosen such that the maximum operating torque would be the same as for Enzian IV.

2. Performance.

It was hoped to reach Mach numbers in the region of 1.6 to 2.0. This large increase of speed over the Enzian IV was claimed to be obtained by (a) the increased thrust, (b) the smaller wing thickness and ogival nose on the body and (c) by the smaller weight. The very large sweepback was provided for reducing the drag in the sonic region; it would clearly have very little advantage at super-sonic velocities.

Provision was made for lateral acceleration of 3.0 to 3.5 g which would be reached at a wing incidence of above 3 degrees. In fact, the limitation of 3 degrees on the wing incidence above which the drag would become prohibitive led to the four winged design. The manoeuvability of a two winged missile would have been small.

The minimum turning radius was given as 1500 m.

The range was to have been approximately the same as the Enzian IV.

The weapon was to have a high degree of static stability; the C.G. margin provided at M.= 16 was 0.505 C.

Calculations regarding wing areas, static stability drag, etc. appear to have been made fairly crudely. In designing the wing plan form Schlichting's finite aspect ratio wing theory was used with no correction for body interference. In using the Schlichting formula the aspect ratio was taken to be that appropriate to a single wing. This was said to be justified by supersonic wind tunnel tests unlike the A4 and Wasserfall designs.

III. PROPULSION UNITS.

1. The motor is a bi-fuel liquid rocket designed by Dr. Konrad of Tech. High School of Berlin to replace an unsatisfactory unit designed by Walther of Kiel. It uses salbei (92% HNO_3 + 8% H_2SO_4) and gasoline in the ratio of 1.4: 1 by weight; the total quantity of propellant bring 550 kg, and the total impulse being 108,000 - 110,000 kg secs. This corresponds to a mean S.I. of 199 but Wurster stated that the mean propellant consumption was 5.5 gm/sec/kg, rising to 5.6 at beginning and end, which corresponds to a S.I. of approximately 182. This mixture is not spontaneously inflammable but require spark ignition and Wurster said that they used a small electrical ignited powder rocket in the combustion chamber to effect ignition. The advantage of the system is that it gives quicker and smoother ignition with less risk of explosion than spontaneous combustion but in order to eliminate explosions it was still necessary to ensure that the salbei feed starts before the fuel feed. (See para.4 below).

2. The propulsion unit comprises a combustion chamber and 3 spherical pressure vessels, the rear-most of which is an air bottle, originally inflated to a pressure of 200 atmos, and the other two contain fuel and oxidant respectively. This disposition was selected from C.G. considerations.

3. At the commencement of burning the rocket motor of Enzian IV operates at a pressure of 34 atmospheres and gives a thrust of 2000 kg and this thrust falls linearly with time to give, at the end of burning, an operating preessure of 18 atmosphere and a thrust of 1000-kg. The pressure reduction between the air bottle and liquid vessels is by means of a simple orifice plate and the progressive reduction in combustion chamber operating pressure is the direct result of gradual exhaustion of the air bottle. The same pressure is applied to both liquids and Wurster said that metering is effected by the resistance of the connecting pipes and not that of the spray nozzles.

4. Retention of the liquids in the vessels is effected by means of bursting discs selected to rupture at 15 atmospheres at entry and 36 atmospheres at exit. In order to avoid explosions on starting the rocket the oxident supply pipes are made shorter than the fuel pipes and the oxidant bursting discs are set to a slightly lower pressure than the fuel ones.

5. Wurster stated that according to German figures the use of air pressure for fuel feed purposes is lighter than a turbine-cum-pump

unit for impulses up to 200,000 kg secs and in addition has a great advantage in that no run up to speed is required. He said that on Me 163 it takes 4-5 seconds to run the turbine up to its operation speed of 30,000 rpm and this delay is prohibitive for a flak rocket.

6. Wurster stated that the weights of the various parts of the motor are as folows :

Combustion Chamber	24 kg
Air Bottles	19 kg
Large Spherical Tank	30 kg
Small Spherical Tank	24 kg
Total	97 kg
Propellant	550 kg

Effective S.I. of motor plus fuel $= 199 \times \frac{550}{647} = 170.$

He said that all tanks were made of ordinary M.S., 2mm thick untreated against corrosion and that the General Staff requirement was that they should stand 6 months storage after being filled with salbei and fuel. No enamel or other protective coating was employed.

7. In addition to this main rocket motor Enzian employed 4 boost rockets giving a thrust of 1500 kg secs each and having burning time of 4 seconds after which they were jettisoned. These rockets were fitted with small wings to assist them to fly clear when jettisoned. Control of Enzian commenced 1 second after jettisoning, i.e. 5 seconds after launching.

8. In the case of Enzian V the initial and final thrusts were increased to 2500 and 1500 kgs respectively by increasing the diameter of the air metering orifice. Otherwise the motor was unaltered.

IV. CONTROL SYSTEM.

A. Gyro Stabilization:

1. Interrogation of Dr. Wurster produced very little acceptable information concerning gyro-control of Enzian. His statements were often changed when questioned so it is to be concluded that his information of actual gyro control was incomplete.

2. However other sources of information produce the following plausible story. The first trial models probably had one rate gyro and one free gyro with a single gymbal ring. The first free gyro tried was found unsatisfactory since it had an angular range of only 40 degrees and no provision for anti-topple. This was replaced in subsequent trial by a gyro which had two gymbal rings with a precessing mechanism for keeping them at right angles. Later it was found that

the stability of the missile was such that pitch gyro's were not needed, thus, only a rate gyro was retained in the last trials.

B. Trajectory (Flight) Control System.

1. The radio control problem in "Enzian" was not as complicated as that encountered in Wasserfall. This simplicity can be contributed to three factors : (a) The angular launching, (b) the aerodynamic stability of the missile, and (3) the subsonic speed in flight.

2. Very little thought had been given to the radio control, the acceptance of already developed radio equipment being anticipated. Under conditions of clear visibility, the use of an optical range-finder such as is normally used for Flak prediction was anticipated. Due to the angular launching of Enzian, it would be easy to follow the missile through its complete trajectory.

3. Flight tests were conducted to check the ground radio control link. (see Flights 20-30 and 30-38 in the following paragraph using the E-230 receiver and the FuG 203 transmitter. The system was known as the "Kehlgerät" and the code name for the receiver was "Strassburg" and the transmitter was "Kehl". A complete description of the "Kehlgerät" is given in the description of the HS series of guided missiles earlier in this report.

4. Dr. Wurster stated that it was intended to adapt the "Enzian" control system for the use of a 50-cm radio control link system called "Kogge" employing the "Brigg E-531" receiver and the "Kran" FuG 512 transmitter. This system was never produced but was being designed by Telefunken GmbH, Berlin. It was further anticipated that radar (Mannheim) would be used at excessive ranges or under conditions of low visibility. However, little actual work had been done on this form of control.

5. The servo motors for moving the control flaps were controlled through a "Mischgerät" or mixing apparatus which consisted of a circular iron core with one output winding to the servo-motor control and several input windings. In the "Enzian" the output from the radio-receiver and from the gyro's were mixed in the "Mischgeräte" and a combination of these two voltages fed to the servo-motors.

V. TRIAL FLIGHT DATA.

1. Flights 1 - 12.

The primary object of the first set of test flights, 1 to 12, was to investigate the performance of the power plant and for this purpose the models used had fixed controls. Other problems examined were the longitudinal stability of the missile and launching conditions. The only real difficulties encountered were with the simultaneous ignition of his four boost rockets.

2. Flights 13 - 20.

Flights 13 to 20 were made on models having the controls operating. A single gyroscope system consisting of a rate gyro and a Siemans free gyro with only one gymbal ring which was used for roll stabilization; there was no control from the ground. The elevator was fixed throughout the flight.

The aim of the tests was to examine the functioning of the roll stabilization. It was found that the Siemens gyro was unsatisfactory since it had an angular range of only 40 degrees and no provision for anti-topple. It was subsequently replaced by a gyroscope made by Hom of Leipzig which had to gymbal rings with a precessing mechanism for keeping them at right angles.

3. Flights 20 to 30.

A pitch gyroscope system containing a free gyro and a rate gyro was introduced and the ground control radio link was put into operation. It was found that the pitch gyro stabilization was unnecessary since the inherent stability of the missile was adequate for dealing with disturbance in pitch. Moreover, it was found that the time-lag associated with the gyroscope servo motor system made the response to elevator movement more sluggish. Consequently all the pitch gyroscopes were removed.

4. Flights 30 to 38.

The final flights consisted of an overall check on the performance, stability and controllability of the missile. According to Wurster these were found to be quite satisfactory. It may be noted that all the above trials were made with the original Walther motor (Enzian I) which was less powerful than the Konrad motor for the final design; the ratio of thrusts was roughly 1:2. It may, therefore, be expected that the maximum speed of 240 m/s at 7000 m (i.e. M = 0.79) measured in these tests should be considerably exceeded with the Konrad installation (Enzian IV)

D - Komet 2

I. Conclusion:

The Guided Missile project Komet 2 is not considered practical in its present form. However, it is a comparatively new approach to German guiding method, and some of the principles suggested maybe useful in future developements of Allied G/M's.

II. General Information

1. The original drawing of Komet II along with a Tech. Report in German by Rogge, was turned over to CIOS Team 367 by the 3rd Army Intelligence Center, Freising, for exploitation. This original drawing was reproduced by ATI-USSTAF at Ober Ammergow, 4 copies going to Lt. Col. Gifford at Ober Ammergow, 1 copy going to Nav. Tech.Mis.U., and five copies being held by CIOS Team 367 for their Team Report. The Technical Report by Rogge was translated by 8th Army A.C. personnel in Freising, but was not available in time for the Interrogation of Rogge.

2. Komet II, a private enterprise , was a flak rocket designed by two Germans, Helmut Rogge and Hans Keller. Keller was unavailable for interrogation because he was, when last reported, living in Altenburg, near Halle, Saale, which was in Russian hands. However, Rogge reports that Keller was the man responsible for the Aero-dynamics and Rocket Propulsion design, while he (Rogge) was the designer of the control system (Vacuum Servo's) and the information unit - (Radar).

III. Analysis of Drawing

1. Two translations of Rogge's technical explanation are available, neither of which are reliable, therefore, the following is an explanation of the drawing, combining information obtained from both translations plus information from interrogation.

2. Komet II , as a flak rocket, has never been completed and tested, however, Rogge states that ground trials of the radar section of the automatic homing device have been tested and approved.

The original homing principle was as follows:- The ground radar, having a fairly narrow beam, is directed onto the target, usually a plane, and the rocket homes on the radar waves which are reflected from the target

3. The drawing is full scale, measurements being shown in mm. The tail section consists of a steel casting (44) with driving vents (45,48). Four stabalizing fins (46), made of compressed plastic, are fastened into the grooves (47).

The flow of gasses from the solid fuel is kept evenly distributed by the action of the distributer (42), which is placed at the center of the combustion chamber. A 90° rotated view of the distributer plate (42) is shown above its position in the rocket. A hole (43) leading from the combustion chamber to the steering gas tube (32) seemingly has no logical explanation. A vacuum is created, which would draw air from the openings in the steering jets, and probably create some vacuum in the control servo. However, during the initial acceleration, it was anticipated to use only surface steering, consequently the vacuum for servo control would not be necessary. Further, a vacuum would draw air through the steering jets, past the vacuum venturiis in the opposite direction to normal operation, probably further reducing the pressure differential and providing little, if any, useful vacuum. A direct question to Rogge on this point produced no explanation except that a vacuum may be necessary in the first few seconds of acceleration.

4. The major portion of the Rocket body contains two driving charges. The starting charge (33) has a fast rate of burning, and is used for original take off and acceleration. The second charge, (28) is a slower burning fuel, and is used to maintain the rocket speed at between 400 and 450 M/S. Both fuel compositions are compressed into steel fuel tanks (34 and 29) with the steering - gastube (32) in place.

5. The charge is started electrically by detonating the high explosive charge (39) by means of the electrical detonator (35), thru the electrical contacts (37) by an external power source. When the fast burning charge (33) is burned, the slower burning charge (28) is ignited by contact. During the burning of the high acceleration charge, (3 to 4 seconds) steering is accomplished by means of steering surfaces only. However, when the slower burning charge (28) is ignited, jet steering is started. Part of the gasses from the fuel (28) pass through the openings (27) into the steering.- gas-tube (32). These gasses pass up toward the front of the rocket, and are divided so that equal portions of the gasses pass out through each of the four steering jets (15-16).

6. After the starting charge is burned, 3 to 4 seconds, and the slower burning fuel commences to burn, the jet steering becomes operative and the second act of steering commences. The gasses from the fuel begin to flow through the four steering jets. These gasses pass the venturi apatures (not numbered) in each of the four steering jet lead pipes, creating a vacuum in the servo-vacuum chamber just behind the magnetically operated escape valve (50). Thus a vacuum is continuously maintained.

7. Electrically, each steering jet has an antenna (half wave center fed dipole) set at 45° to the axis of the steering jet (13). The two antenna's controlling the azimuth steering jets are placed at 90° to each other. Thus, if the axis of the missile (facing forward) is 0° then the antenna on the top steering jet would be at 45° and the antenna on the bottom steering jet would be at 315°. The same condition would exist on the left and right steering jet antenna's. The antenna pattern of these antenna's would be such that there would be an equal pickup

from a target if the axis of the steering jets were facing the target. Each steering jet would contain a detector unit (10 and 12) and it would be necessary that the gain of the two detectors was exactly the same. This is very difficult to obtain in practice, and offers a serious objection to the system.

8. The steering jets are controlled in the following manner. The steering jets are facing the line of flight before the jet power takes over due to their aerodynamic shape, (see 90° view of lower jet). As soon as the gasses begin to pass out the steering jets, the vacuum servo-mechanism becomes operative. If one of the antenna's is receiving more power from the target than the other one in the same plane, the rectified power delivered to the magnetic coil (11) is larger than that delivered to the magnetic coil opposing it. Therefore, the solenoid (52) moves the escape valve (50) toward the coil receiving the larger current. This causes the escape hole (51) to coincide with the escape aperature from the pressure chamber (5) and a pressure reduction results. At the same time the pressure in the corresponding chamber of the opposite cylinder is brought to atmospheric due to the escape arrangement of the escape valve (50). Thus atmospheric pressure results on one piston, while vacuum is created on the other piston (6). The piston chamber is sealed by the oil soaked ring (49). Since the two pistons operating the steering jets in one plane are coupled together by a coupling rod (7), the two pistons must move together. The movement of the piston (6) is transferred by the gear arrangement (7,53 and 54) held in place by the supports (8 and 55) to cause a movement of the steering jets with respect to the axis of the missile. The steering jet moves on bearings, and are held to the missile by the locking action of (57). Thus it is supposed that the steering jets are locked to the target as soon as the vacuum-servo's become operative.

9. In the other plane it is necessary to offset the vacuum servo as shown by (4) and additional drawing shown above the steering jet. This requires that the gearing mechanism (53 and 54) be driven by a pully system (56).

10. Batteries (2 and 3) are located forward of the servo-mechanism in the nose of the missile (1) for operating the detector equipment.

11. The casing of the steering control (9) consists of two sections made of compressed material which are shaped into a Keel-shape for aerodynamic facing of the steering jet in the first act of steering.

12. The warhead (22 and 24) and the fusing system (19,20,21 and 23) are circular shaped with a steel jacket (24). The explosive charge weight was not indicated. The fuse was described as a sensitive magnetic detonator and probably referres to a proximity fuse which the designer had heard about. No details were known. The fuse as shown will operate on collision or will destroy itself when the fuel is completely burned.

IV. Evaluation

1. Komet II is a private enterprise in the Guided Missile field and probably never reached a stage much further than the attached drawing.

2. The jet steering is slightly different than most German approaches to the problem of steering, however, no tests have been completed to establish its practicability. The fact that the radio equipment must be accurately balanced and remain so during flight is a serious objection. Further the fact that the antenna's move with the steering jets means that the jets are always facing the target, or source of radar energy. Therefore, as the axis of the missile approaches colinearity the turning force becomes less due to the angle of the axis of the jet with respect to the axis of the missile. Thus, the missile will tend to oscillate, both in the L/R and in the U/D directions. Further, the antenna system, as shown, has a poor directional characteristic, tending to cause greater oscillation about a linear course. However, a redesign of the intelligence head would be possible which would eliminate this objection.

3. The designer intended that the operation of the missile would be as follows:- The target (plane) would be detected by ground radar (on 50 cm) and held in the radar beam. The missile would be launched to intercept the target after a given flight time. No information was available on launching method. It was then intended that after 3 to 4 seconds the homing device would take control of steering the missile (second act of steering). The radar energy reflected from the plane was to act as the steering energy source. The effect of the large metal mass of the missile itself on the antenna pattern was not considered by the designer, nor was the fact that the radar energy source of the ground station was much greater than the reflected energy from the plane and either the missile would tend to home on the ground radar station, or move likely, the interference caused by the ground station on the rearward lobe of the antenna would completely disrupt the homing device.

4. However, the use of a balanced pickup and detector system, along with a device for homing on a plane carrying radar equipment may be practical. This would require complete homing redesign.

E. TIAFUN (UNGUIDED)

I. General Description. (Interrogation of Klaus Scheufelen.)

a. Scheufelen is an engineer by training and is co-owner of a paper making factory at Oberlennengen in Wurtemburg. He was called up into the army in August 1939 and was a flak officer at Brest until November 1942. He was then transferred to the A.A. weapon test station on the island of Usedom where he had associations with Peenemunde and H.A.P.11 and finally became a range officer concerned with the firing trials of Wasserfall. In all he spent 2½ years working with the Peenemunde people and up to January 1945 he said that the number of Wasserfalls fired was 20 to 30 or possibly 40.

b. As a result of his experience on Wasserfall and other rockets, Scheufelen came to the conclusion that better ballistics could be obtained from liquid than solid fuel rockets on account of the more uniform efflux, the absence of solid particles in the jet and the absence of tortuous passages past the propellant pellet in the combustion chamber. He accordingly started work on his own initiative on a 10cm. calibre liquid fuel flak rocket. In September 1944, when he was satisfied that his theories were correct he put his proposal forward to the "Reich Luftfart Ministerium" and after due ~~scruting~~ sorting it was accepted for production and the design was "frozen" as from October 1944. This project was given the code name "TAIFUN". and Scheufelen was made the "sachbearbeiter" (Admin.Officer) in charge of it at Elektromechanische Werke G.m.b.H. at Karlshagen in Pomerania.

c. The motor is a bi-fuel one running on a Salbei (99% HNO_3 or 90% HNO_3 + 10% H_2SO_4) - Amine fuel mixture (Aniline + Orthodioxy benzol?) which is spontaneously inflammable. The salbei is contained in the inner tank (1) which in the first instance was made of aluminium 2mm. thick but was later made of enamelled steel 0.5mm. thick on account of the shortage of aluminium. The use of thin steel increased the tank capacity of 5% and these steel tanks are said to have a storage life of at least 3 months. The reason for adding the H_2SO_4 to HNO_3 was to reduce corrosion. The fuel was contained in the annular space (2) between the rocket wall and the inner tank and injection of salbei and fuel into the combustion chamber (3) was through two concentric rings of jets (4) and (5) inclined at 50° and 40° to the axis respectively. At first two rows of 24 holes in each row $2.05^{+0.06}_{-0.03}$ and $1.25^{+0.06}_{-0.03}$ m.m. diam. for salbei and fuel respectively were used but later these were changed to 2 rows of 18 holes 2.40 and 1.45 mm. diam. respectively to reduce the risk of blockage. The propellant is retained in the tanks by means of thin aluminium bursting discs (6),(7),(8) and (9) at the top and bottom of the tanks. These discs are suitably indented to facilitate bursting and provided that both the inner and outer bursting discs (Salbei and fuel respectively) burst simultaneously, there is no pressure difference across the wall of the inner tank and it can be made of very thin metal. Immediately adjacent to the upper bursting discs is a perforated plate (10) used to centralize the inner tank.

d. The pressure for feeding the propellant into the combustion chamber is obtained from a small pellet of ordinary rocket powder located in the small chamber (14) above the tanks. This pellet is electrically ignited by induction when it is desired to fire the rocket and is burned at a pressure of 150 atmospheres. This pressure is reduced to 60 atmospheres in the tanks by means of the orifice plates (10) and (11), the former having 1 central hole 8.0 mm. diam. communicating with the Salbei tank and a ring of 4 holes 4 mm. diam. connecting with the fuel tank. The pressure in the combustion chamber is 50 atmospheres and the pressure drop through the injection holes is accordingly 10 atmospheres.

e. Scheufelen said that the pressures developed in the tanks during storage, due to changes in temperature, do not exceed 5 atmospheres and that the rocket itself will function satisfactorily over the temperature range -30 to +40°C, the only difference in performance being that due to the change in temperature and therefore density of the propellant gasses.

f. Scheufelen said that the combustion chamber was made from an ordinary deep drawing steel sheet which is first bent around and welded and then spun to shape and that its volume was determined experimentally by starting with a small one and gradually increasing the volume until satisfactory combustion was achieved. He had no figures on the minimum permissible values of $\frac{V}{At}$ where V= volume of combustion chamber and At = throat area but stated that the only way of reducing this ratio is to increase the chamber pressure. He, however, claimed that a value of 900 Kg secs per litre for the ration $\frac{\text{Impulse}}{\text{combustion chamber volume}}$ was much higher than was obtained on V.2.

g. He relied on spontaneous reaction of the Salbei and fuel for ignition and in the early stages experienced considerable trouble with explosions due to the accummlation of too much propellant in the chamber if ignition did not take place within 0.002 second. These explosions destroyed the combustion chamber and Scheufelen suspected that they may have been using a combustion chamber of the wrong size but in order to overcome them in the limited time at his disposal he originated a regulating device of known design.

II. Experimental Results

a. On account of the initial acceleration and the different densities of the Salbei and fuel, Scheufelen found it necessary to carry out firing trials to determine the correct ratio of jet sizes and during these trials he found that if there was as much as 0.5 Kg. excess of fuel or oxidant remaining in the rocket after combustion was complete, it upset the ballistic accuracy very badly. He also found it essential that the axis of the venturi should be accurately coincident with the axis of the rocket and to check this he made a test rig on which the rocket was mounted by means of a rotating taper plug fitting into the divergent cone of the venturi so that the eccentricity at the nose could be measured. Following this discovery he went to selective assembly of the experimental models and asked for 10,000 further models for ballistic trials, so as to ensure that mass production and not hand methods would be used in their construction.

b. To improve the ballistic accuracy he also found it desirable to twist the projector rails so as to impart an initial spin more rapid than the resonant frequency. By this Scheufelen presumably meant that the rate of rotation should be more rapid than the rate of oscillation in pitch or yaw, so as to avoid any possibility of resonance developing as a result of an asymmetrical gas jet.

c. Scheufelen said that his firing trials indicated that the projectile did not fly yawed as had been predicted from the wind tunnel tests and also that its drag was slightly less than predicted. As a result of this he was able to reduce the span of the fins from 240 to 200 mms. He said that the maximum velocity attained in the trials was just over 1000 metres per second and that he did not anticipate any troubles to result from putting up the velocity to 1200 metres per second by reducing the burning time and by raising the combustion chamber pressure to 100 atmospheres. He said that the time of flight to 10,000 meters was 14 seconds and the residual velocity at 14,000 metres was 300 metres/sec. which compares very favourably with the time of flight of an 88mm. shell viz. 28 secs. to 9,000 metres.

III. <u>Fuzing and Warhead</u>

a. The warhead of Taifun could either contain 0.5 or 1.2 Kg. of H.E.(12) and a "graze fuze" made by Rheinmetal was always used, together with a 20 second pyrotechnic self distruction time fuze (13) ignited by the pellet of rocket composition used to expell the propellant.

b. The theory behind the use of a percussion fuze and small warhead is as follows:-

let $\frac{1}{b}$ = probability that the aim will be correct in azimuth.

$\frac{1}{m}$ = ...ditto.....in elevation

$\frac{1}{n}$ = probability that a time fuze will be set to burstat the correct range.

a = projected area of target aircraft

A = The area in which a burst at the correct range will prove lethal to the target aircraft

$\frac{1}{b \times m}$ = probability of a direct hit

$\frac{A}{a} \quad \frac{1}{b \times m \times n}$ = probability of securing a hit by means of a time delay fuse.

According to the Germans the increase in aircraft size to the heavy bomber has so decreased the ratio $\frac{A}{a}$ that

$$\frac{1}{b \times m} > \frac{A}{a} = \frac{1}{b \times m \times n}$$

c. Scheufelen said that he supported the above theory and favoured the use of a percussion rather than a time fuze on the grounds of increasing the possibility of bringing down a bomber and he claimed that all the flak specialists shared this view. He said that in good weather optical sighting is the best as regards azimuth and elevation but Radar is the best as regards range. In bad weather the advantage swings over in favour of Radar for everything. He claimed that towards the end of the war the Germans were securing approximately 1 kill for 2000 rounds fired but that under unfavourable conditions the figure rose to as much as 15,000 rounds per kill.

d. In adition to the above, Scheufelen had used time fuzes on experimental firings so as to get an extra point on the trajectory beyond the normal range of a kine-theodolite.

e. Besides the normal electric percussion fuze which is armed by a wipe contact as the round moves up the rails, Scheufelen said that work was in hand by Menda Radio of Dresden on fuzes in which the air friction and/or magnetic induction on leaving the rails were used to arm the fuze.

IV. Further Developments etc.

a. Scheufelen said that he had no knowledge of any proposal to make a guided version of Taifun. On the contrary he claimed that the increased effectiveness of Taifun as a flak weapon as compared with the standard 88 mm. gun arises from the shorter time of flight - 14 secs. to 10,000 meters instead of 28 to 9,000 metres - and also the increased rate of fire attainable by replacing the barrel of an 88 mm. gun by a '30 barrel' multiple projector. He claimed that the change over could be effected in less than 1 day.

b. In addition to its use as a flak rocket, Scheufelen was considering the use of single and 8 barrel portable projectors for infantry motorised or naval use.

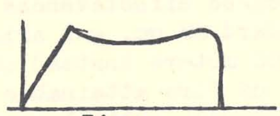
c. Scheufelen claimed that the cost per round was only about 1/3 of that of 88 mm. gun ammunition and that the cost could be further reduced without reducing the performance, by reducing the calibre to 7cms (so reducing the weight of salbei from 7.5 to 4.0 Kg.), as the weight, the drag and the quantity of fuel would all be reduced in the same proportion. Reducing the calibre to 5cm. would however result in too flimsy a projectile.

d. He claimed that befuel propulsion units of the Taifun pattern could be produced in calibres up to 30 cms without detriment to the performance: also that the performance of the 10cm model could be improved by increasing the tube thickness from 1 to 1.3 mm., when the better welding conditions should allow the chamber pressure to be raised to 100 atmospheres

V. <u>Leading Particulars of Taifun as 'frozen' in October 1944.</u>

Calibre	10 cms.
Overall length	193 cms.
(This should be increased to 223 cms. for best results)	
Width across fins	Originally 24 cms. but later reduced to 20cms.
Number of fins	4
All-up weight	20.3 Kg.
Total weight of warhead	2.0 Kg
Weight of H.E. filling of warhead	0.5 Kg.
(or 1.2 Kg. with all-up weight of 21 Kg.)	
Total weight of Propellant	10.8 Kg.
Weight of Salbei	8.3 Kg.
(90% HNO_3 + 10% H_2SO_4)	
Weight of fuel	2.5 Kg.
Dry weight of motor + powder pellet	7.5 Kg.
Thrust	840 Kg.
Impulse	2100 Kg. seconds
Burning time	2.5 seconds
Specific impulse	194 $\frac{\text{Kg. secs}}{\text{Kg.}}$
Equivalent S.I. of fuel + motor	115 $\frac{\text{Kg. secs}}{\text{Kg.}}$
Combustion chamber pressure	50 atmospheres

Shape of thrust time curve



Time

Initial acceleration	416 g.
Maximum velocity	over 1000 m/sec
Residual velocity at 14,000 metres	300 m/sec
Time to reach 10,000 metres	14 secs.

3. TECHNICAL ANALYSIS of HOMING DEVICES

A - MADRID

1. Preliminary report on Madrid.

A. General

Madrid was an infra-red homing device developed by the firm of KEPKA in Wien. It was intended for use with the missile Enzian. The firm was really a joint affair between Kepka and Baron von Pfeiffer, the former dealing with the business side in connection with the production Ministries and the latter with the research side. When the fall of Wien became imminent the firm was evacuated to Bad Hallein but before work could be started up there, there came the general collapse. Kepka hid the only model of the Madrid equipment to save it from destruction by the S.S. He was taken to Augsburg by the U.S. authorities where he was first interrogated by this team. He volunteered to produce the equipment if taken back to Bad Hallein and so this was organised.

B. Interrogation of Kepka

The Madrid set is a locked follow infra-red eye which weighs about 20lbs complete. It has a 25cm. diameter spherical mirror of about 15cm. focal length. The mirror is of glass, silvered on the upper surface. At the focus of the mirror is a rotating shutter which has a 90° sector removed. As this scans the image of a target, the radiation is interupted for three-quarters of a revolution and is transmitted during the remainder. The transmitted radiation is diffused onto the surface of a small Elac photocell by passing it through a tube with rough walls. This avoids trouble due to the variation of sensitivity of the photocell at different points on the surface. The shutter rotates at a speed of 40 rps and is driven by a small impulse motor. The cell is connected in a bridge circuit and has 100 volts across it. Its output, which is a 3:1 space to mark square wave is amplified in a four stage amplifier using 3 P 2000's and one P 3000 as output valve. The output is fed into a solenoid which operates an air valve, letting air into a distribution chamber. A disc with four holes rotates in this chamber, and is driven by a small D.C. motor. This motor also drives a four way commutator which energises in turn the four holes of the shutter impulse motor. If therefore, the shutter and the disc are lined up to start with, and the motor is switched on, the two run in synchronism. Furthermore, the inertia of the shutter is so small that if the motor is stopped suddenly, then provided that the impulse motor is still energised, the shutter does not run out of step.

The mirror is pivotted about two mutually perpendicular axes which lie approximately in its aperture plane. The supporting members are semicircular and are machined to form rails which run between grooved wheel supports. The supporting wheels for the outer semicircular member are on the fixed part of the equipment itself while those for the inner member slide on the outer support. The mirror is slewed round by means of flexible steel cables attached to semicircular supports. The cables are gripped by clamps attached to small levers which are actuated by diaphragms, so that when air is blown into either of four chambers the mirror makes a discrete movement of about 1° in either left, right, up or down direction. The shutter and the air distributor disc are so synchonised that if a signal is received in the upper quadrant, the diaphragm actuating an upward motion is energised, and so on. In this way the eye orientates itself in the direction of the target, but owing to the fact that its motion is in discrete steps of 1° it always has a random vibration of this magnitude. The accuracy of the mean position was said to be 0.1°. The total field of view was +/- 3.0°. The sensitivity of the device was said to be such that it could lock on a black body radiating 1 watt at a temperature of about 600° c. at a distance of 360m. This corresponds to a sensitivity of 3×10^{-7} watts falling on the cell, assuming no atmospheric absorption.

Both supporting members have potentiometers with pickoffs attached so the two components of the angle turned through by the eye with respect to the support are produced as D.C. voltages. The maximum angle which the eye can turn through is +/- 50°, but this can be increased at the expense of extra mechanical complication. The eye was intended to be used for pursuit homing, in which case the missile was given a rate of turn which was proportional to the angular misslignment of the target. It would also be possible to use it for predicted homing but in this case the use of bang-bang rudder would appear to be necessary since the eye makes discontinuous jumps about the true direction of the target, and instantaneous measurement of the rate of change of direction of the target is impossible.

Work had also been done on the reduction of microphonics in the Elac cell. This was along the same lines as mentioned in the report of the interrogation of Dr. Kaspar of A.E.G., namely that of silvering the inside surface of the cooling tube, to avoid dielectric variations caused by vibrations of the solid CO_2, and also by making the leads to the cell as rigid as possible.

Kepka is anxious to make some of these sets of equipment and said that work could be started immediately.

C. <u>Interrogation of Pfeiffer.</u>

Pfeiffer was in hospital in Salzburg. He complicated matters by saying that he was not willing to co-operate further with Kepka, and that about twenty of the people formerly working for the firm were also of the same mind. He said he had ideas for making a much more compact version of the Madrid set and wanted to be allowed to form a small group to work for the Allies in developing this equipment.

The new form of the equipment was to have a 16cm. mirror with a focal length of about 30cm. The outer annulis of the mirror, 5cms wide, only, was to be used and by using annular shaped plane mirrors between the cell and the objective the distance between the cell and the mirror was to be reduced. The scanning was to be by means of a rotating plane mirror mounted excentrically on a shaft on the axis of the main mirror, and driven by a motor mounted behind the latter. This motor was also used for driving the mirror scanning mechanism which was to be entirely electric in principle. The idea was to drive a small fly wheel which gave up its energy at equally timed intervals to ratchet inching devices with a solenoid for distributing the impulses between the four directions according to the signals from the eye. In this way the use of a synchronous motor was obviated.

The new beam width was to be +/- 1.5°, and on this account, and also because of less spherical abberation in the new optical system, the range of the smaller set was expected to be of the same order as for the old set. A device for automatic scanning of a 20° field of view when searching for a target was to be incorporated. It was calculated that a complete spiral scan of the whole field would take 0.33 secs.

2. Present Status of Madrid

1. The Madrid equipment was taken to ADI(SC) where all documents were microfilmed and a preliminary study of the apparatus was made. It was the expressed desire of ADI(SC) that several models of the apparatus be manufactured if possible.

2. A complete test of the performance of Madrid is now in the process of being conducted jointly by R.A.F.Farnborough and by TRE - Great Malvern. This includes operation and testing of sensitivity. All the documents have been sent with this equipment.

3. Sq/L. Green of the R.A.F. has started the manufacture of 16 additional models of Madrid at Hallein, Austria. He has Kepka and Pfeiffer at his disposal for completion of the project. Permission for the manufacture has been given by USFA at Salzburg. These equipments, when completed, are to be distributed to both British and American agencies for further test and developement.

3.Future Report on Madrid

A report on the findings of R.A.F. and TRE will be submitted to CICS and to A-2 - Electronics Intelligence - USAFE (Rear) when the testing of Madrid is completed by Mr. R.J.Lees of TRE.

B - DERNA

1. General Information

Appendix 1 to this report shows the mechanical layout for Derna in Wasserfall. The following paragraph is a translation of the German document describing the reasoning and construction of a radar homing device for Guided Missiles. The figures referred to in the description are directly following, so that they can be easily referred to when reading this section of the report.

2. Translation (Control Head for Flak rocket)

Report of a control head of a self homing rocket which will follow a fighter plane course with a radar controlled mechanism in the control head.

A. Problems
B. Course Steering and Stablization and Solutions thereof
C. Type of Radar to be used
D. Special tube for Radar system
E. Research and developement program to achieve results
F. Solutions which had been reached during research and which can be of operational value.

A. Problems:-

The technical operational status of the Luftwaffe at this time and also the developements of the Enemy in the use of un-manned rockets of greater velocity, place upon the future developements of the flak rocket these minimum requirements.

1. Attitude range of 14,000m. (9.68mi.)
2. Horizontal range of 18,000m. (12mi.)

From this arises the necessity of a Radar controlled rocket with a range of 22,000m. (13.6mi.). With the assumption that the speed of the rocket is still under the speed of sound, the control mechanism must be made so it is possible to hit high speed targets. Which means, that the flight curve of the attack is not omitted from the front but is allowed to be the main angle of attack (computed collision course).

In order to hold the speed losses, due to necessary rudder changes and drag, are small; it is essential that the total number of course changes be held as small as possible. Which means, the rocket's accelleration must be held as small as possible (i.e.) dare never be any greater than the speed attained during flight to the target.

In order to launch a large scale attack and to transmit the target information to other installations at the same time and as singly as possible, the launchings must be made at as large a target as possible. The control head must also have the ability to automatically correct for any deviation from its proper course to the target at any given moment.

It is brought out, that the radar equipment in the control head picks up the target at the moment of launching. In order to mullify enemy defense measures, a mass launching is necessary which must for reasons of production capacity makes possible the technical release of the projectile with a minimum of required material.

B. <u>Course Steering and Stabalization and Solution thereof</u>.

1. The Fighter Path Precedure
2. Stabalization Procedure

1. The requirements in (A), to have the attack upon the target from the front, is made possible, theoretically by use of a fighter course curve (collision course).

The fighter course curve is mathematical taking into consideration a group of fighter course curves. The fighter course is a leading course, which takes the most direct path to the target. By changing of launching speed or aiming direction of the projectile or of both, the present course must be directed by the new launching information.

The fighter course (curve) therefore, is namely the greater time saving pursuit course.

(Fig.1): As the directions show, the Angle (E_a) between a definite aiming area and the aimed projectile target remains constant.

If the target changes once, in speed or direction, a new flight course will be taken. It is pointed out, that by continuation of the old course, the Angle E_a will change. In order to get on proper course the changing of the Angle must be compensated for until Angle E_a is constant again. If the target changes its speed and direction, the resulting change of Angle will be so changed that the line of flight will be at a minimum. The path then taken will be a pursuit curve.

As in report 1 and also "Research and Reports Nr; 650: In regard to several kinds of pursuit Curve" from Dobbrach and Knothe, shows, accelleations are no greater at launching period than at the target impact time but namely the same. (Here with 10g assumed). Thus are the requirement of least possible path changes fulfilled. In order to fly the described pursuit curve, it is necessary that the magnitude of the Angle E_a is watched and pursuid. This happens as follows:

(Fig 2): In the head of the missile, there is a directing antenna system (reflector with rotating dipole). A switching antenna pattern determines the course of the target. The split field direction finding system is so operated, that the dipole is not in the focal point of the reflector but slightly off center, but in the electrical axis of a standing wave. There is, at the same time, a feederline between dipole and radar transmitter. With the rotation of the axel, the dipole is alternately left and right of the focal point. The dipole is the TX/RX antenna (Fig 3) of the radar set. The reflected signals which are picked up from each dipole antenna pattern are compared in the radar set and detects any variation of direction to the target from the electrical axis of the directional antenna system (Angle b). The sum of the angle between the electrical axis and an absolute search reference point (Gyro!) - (Angle n) and the angle of deviation of direction to the target from the electrical axis (b) is measured. The angle ( ) is, at the output of the radar set, characteristic of a certain voltage value. The (Angle n) is, during attack, on a variable potentiometer, which is coupled directly to the absolute direction of the Gyro, also indicated by a voltage value. The sum of both voltages gives a definite value of (Angle E_a). If the voltage value changes, so will (Angle E_a) also change. In order to definitely establish this change of voltage, it is impressed upon a load condensor (C1). Steering will be accomplished by the charge and discharge of C_1, because it is a measure of the course changes of E_a. The charge and discharge produces on two resistors R_1 and R_2 a voltage drop of which R_1, a part of the voltage drop, and R_2 voltage drop are fed into power amplifiers V_1 and V_2. Both amplifiers drive an individual relay A and B. The relay contacts (a) of relay A operates the electromagnetically operated rudder. This method establishes only a Black and White control, which is sufficient for a measurement report of stability.

For a practical useable reflector diameter of 45cm. and a frequency of $\lambda = 6$cm, the focusing ratio is 1:7.5. The search area measures up to corresponding values of the Fu SE 64 nearly 20° - 25°. The beam characteristics of the antenna can only be determined by experiment.

(Fig 3): So that the search area of the directional antenna system is consequently reduced, the system is located perpendicular to a navigational swinging axis. The directional antenna system must be so constructed that it can swing thru the necessary Angle E_a of 0° to 90°. The swing is accomplished by using a reversible motor and gears. The control of the motor is accomplished by contact (b) of relay (B). The travers speed is so chosen, that it has the smallest amount of magnitude, at least, but also as large as the largest Angular velocity as the middle turning of the projectile about the verticle axis (~25° per sec). The magnitude of this Angular velocity is determined from the projectiles maximum acceleration, under the assumption that the projectile, over a distance of 900m (Min. curve radius by about 275mp.sec. speed of the projectile), makes no more than 90° false turns in flight. This case never occurs practically, so that the value 25°/sec in no case is put too low.

The described system up to now discussed only the steering of the main flight path of the pursuit curve. A tail lurching of the projectile is, of the present described mechanism, not discussed. A method of Stabalization is necessary. A new stabalization method is not sufficient for the calculated requirements of Report 2 so that a new conformable method of calculating stabilization is necessary. Under "Conformable Methods" of stabilization, one can determine a reasonable rudder value of pursuit course direction, for guiding oneself. It also cannot result in any definite reference point, but must be referred to the target. The Angular change between direction to the target and definite target axis must be measured. This is, in the case of the concerned pursuit courses, in the electrical axis of the reflector. By tail lurching (angle of yaw change), the Angle (b) also changes its magnitude. Steering should be such that it holds the course after changing the Angle. The voltage value from the radar set, which characterizes Angle b, will now be separately led to a load condenser C_2. The charging and discharging of C_2 results in a voltage drop across R_1, which is the input to the grid of amplifier V_1. These charges and discharges also have a control over the ruddercontrol, which is a combination of course maintainance, and stabilization value.

(Fig.4.): If the target travels outside the flight plane, (1) travers plane of the reflector, the projectile must be so turned about its longtitudinal axes, that the target is again in the traverse plane of the reflector, which will then determine the new slant plane, determined by lines of present and future position. (2) The drifting away from traverse plane must also be measured. Until now only the side deviation of the direction to the target from the electrical axis of the directional antenna system through comparison of both extremities of the dipoles receiving energy been determined. Now, from the same, again will be determined the maximum deviation of inclination and declination. (Fig.2).

(Fig.4) The deviation is through (Angle y) and again through it in a represented voltage value, indicated.

(Fig.5) A definite portion of the amount is taken off a voltage divider and fed into a power amplifier V_{12}directly. The amplifier. operates, thru the relay contact a of relay AA, the cross rudder. In order to dampen the resulting rolling action, the voltage value of (Angle γ) is fed to a load condenser at the same time. This charging and discharging of C_3 through resistor R_3 produces a voltage drop which is also fed to the grid of the power amplifier V_{12} and also influences rudder control.

C. Type of Radar to be Used

A range of 35km. is necessary for the type of radar equipment Fu SE 64. (Evenly concentrated Beam). Information from Services Station BHF states that no information could be obtained on transmitter tubes in the cm range with 150 KVA. The necessary transmitting power is about 25KVA.

The principal construction of the transmitter is shown in Fig.6. The received impulses from the antenna go through the Gate (TX/RX switch) (TR Tube) and directly to the receiver. From the RX, the signals go to the signal switch (S_3) which separates the received value of extreme values of azimuth and height in the azimuth or altitude comparison apparatus and are then separated as to Altitude and Azimuth by S_4 and fed to a regulated Amplifier. The Amplified values of Altitude and Azimuth are then separated by S_2 and then fed to the steer mechanism. The regulated voltage for the amplifier is fed through S from the receiver antenna and the amplifier, to a filter circuit. The S_1 switch always switches in the regulator voltage only for extreme conditions of the dipole. This value is necessary in order that, no false indication of Angle value are possible through the changing of reflection characteristics of the target and by increasing receiver signal intensity to the steering mechanism as the target is approached.

The transmitter power is transferred to the dipole through the Gate (TR Tube). The Gate does not allow the transmitter power to enter the receiver. The pulse which triggers the transmitter also provides a voltage to the RX which protects the receiver during transmission time. Fig. 6 shows the connection of the radar apparatus with computer for Altitude and Azimuth (Fig.5 and 3). The voltage values for Altitude are taken from the Altitude computer and then to segement (h) of switch (S_6) which is connected to the contact arm of amplifier V_1 (which is shown in Fig.5 as V_{12}). The voltages for steering are taken from the Azimuth computer and then to segement (S) of switch (S_6). The voltage which operates Relay A and contacts a(aa) is connected by Switch S_8 which is synchonized with S_6 and this voltage will have control over the cross rudder and azimuth rudder. The resulting value of azimuth from the computer are led to amplifier V_2 through S_7 and make possible the operation of the reflector for proper following control. By this method it is possible to make two amplifiers sufficient in the steering mechanism.

Due to efficient engineering methods, the radar set does not transmit during a complete revolution of the dipole, but only in the extreme angle of 30^o (see Fig.6). This is made possible by switch S_5 which is sent to the triggering circuit as a control voltage and serves as a triggering potential for a thyratron.

Supplement: The connections for a roll compensator, that is, a roll compensator for angle of yaw variations which result through relative turning about the flight level of the horizontal axis, are not connected because it seems that compensation for present conditions aren't necessary.

X D. Special Tube for Radar System

In the case that a receiver in the cm region is used in construction, about 12-16 such tubes can be obtained or figured on according to reports from Airplane Research Institute, Oberpheffenhafen. The expenditure for an expendable apparatus as this is too high. A indicator for cm. waves must be employed, which will work in conjunction with a single amplifier which give the necessary power for the steering mechanism. The proposition is now made to use a tube with the following characteristics.

Fig. 7. The electron beam from the electrode (Kathode), must go through a fixed magnetic control field. Here it moves back and forth between deflection plates A, and A_2 upon which is placed a high frequency voltage. The strength of the magnetic field is so chosen that for a certain frequency there is a continual acceleration of the electrons perpendicular to the beam.

The electron speed and length of the control chambers are so chosen that a number of H.F. osc. occur during the time of transit across the control chamber. This results in a certain dispersion of the beam but its small compared to the beam width. The latteral velocity component is impressed on the electrons in the control chamber. The velocity component impressed on the electrons in the control chamber is such that electrons are bent in a strongly curved path in the magnetic field.

The electrons then reach the space when there is no magnetic field and in which the radial components of velocity are maintained. The beam cross section at the end of transit chamber is increased by some 10 times by an electron optical system which accellerates the electrons at the same time very strongly. An anode about as large as the beam image with no high frequency potential is applied, some of the electrons miss the anode which causes a reduction in current (Ip) The potential drop across an external load resistor R_A is fed into an amplifier of about 3 tubes and this actuates the control mechanism.

E. <u>Research and Developement Program to Achieve Results</u>

All the partial developements ought to occur at the same time so as to solve the over-all problem in the least time.

<u>Motive Development</u>

1. Theoretical basis for the overall and for practical problems (essentially completed)
2. Developement of the control mechanism
3. Developement of a radar apparatus which is suitable for this.
   a. As a temporary solution by applying one of the usual centimeter receivers
   b. As a final solution, by using a receiver with a tube yet to be developed.
4. Developement of a new receiving tube for cm waves.

F. <u>Solutions which had been reached during research and which can be of operational value</u>

As a temporary solution, a ~~possesive~~ passive control device for flight toward a beacon.

a. For the two dimensional cases with flight toward flare marked enemy targets with long range cannon.

b. For the three dimensional cases with flight toward transmitting aircraft (Rottordam and Medlow); night fighter search apparatus or experimentally towed flares.

Fig. 1

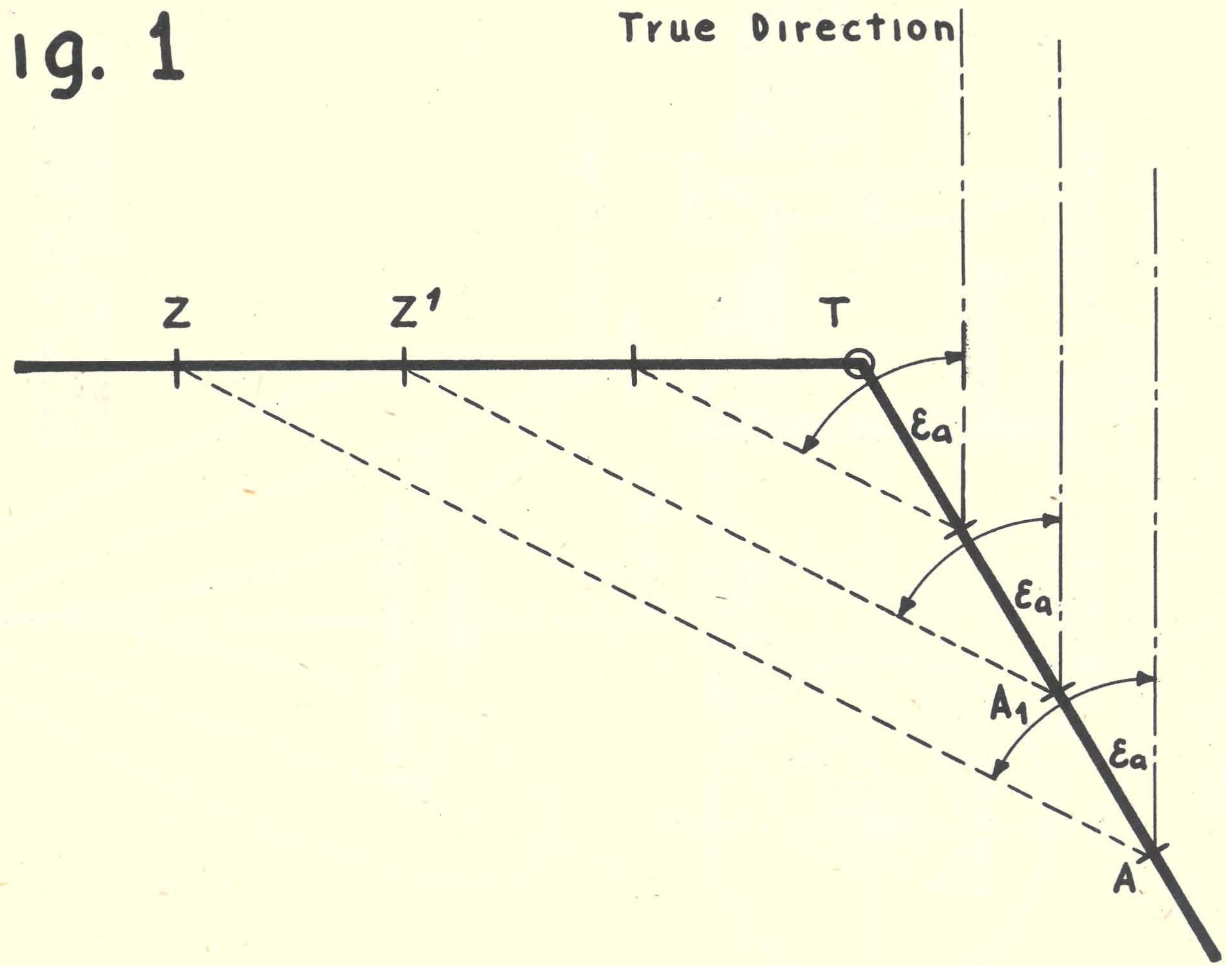

True Direction
Z
Z'
T
ε_a
ε_a
ε_a
A_1
A

Fig. 2

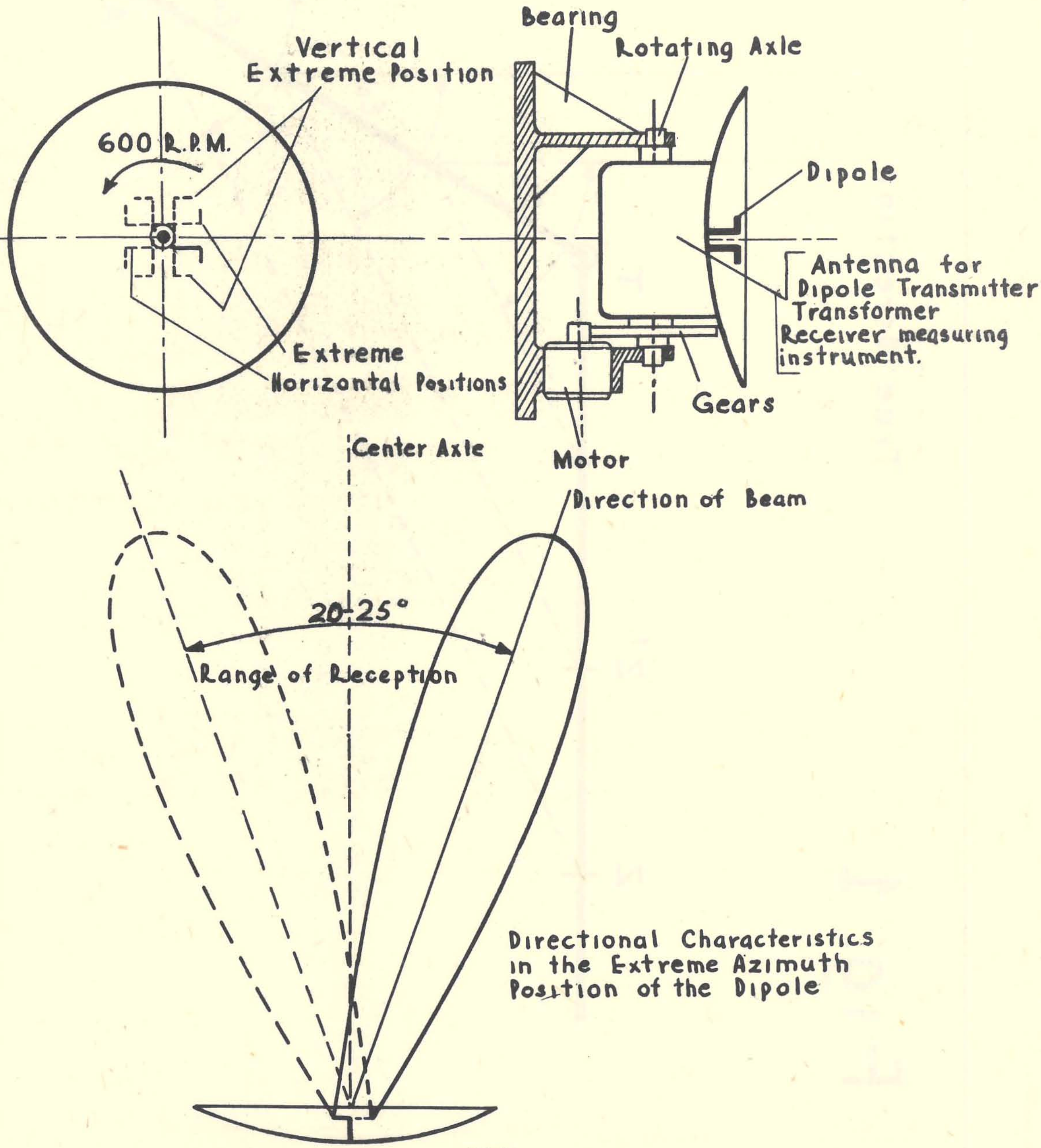

Bearing
Rotating Axle
Vertical
Extreme Position
600 R.P.M.
Dipole
Antenna for
Dipole Transmitter
Transformer
Receiver measuring
instrument.
Extreme
Horizontal Positions
Gears
Center Axle
Motor
Direction of Beam
20-25°
Range of Reception
Directional Characteristics
in the Extreme Azimuth
Position of the Dipole

Fig 3

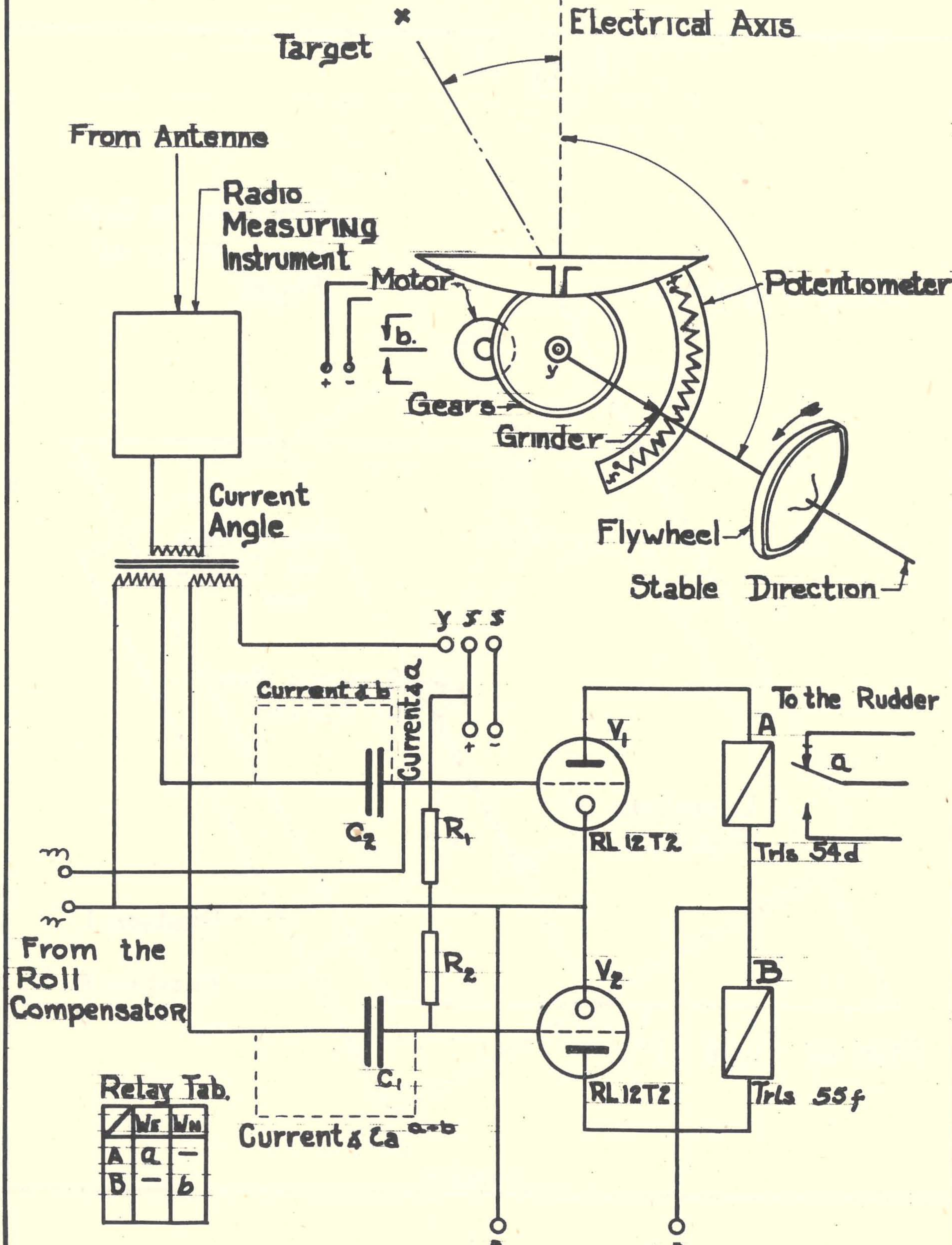

Target
Electrical Axis
From Antenne
Radio Measuring Instrument
Motor
b.
Gears
Grinder
Potentiometer
Flywheel
Stable Direction
Current Angle
y s s
Current a b
Current a
To the Rudder
A
a
V1
C2
R1
RL 12 T2
Trls 54d
From the Roll Compensator
R2
V2
B
C1
RL 12 T2
Trls 55f
Relay Tab.
WF WN
A a —
B — b
Current & Ca a+b
-A
+A

Fig 4

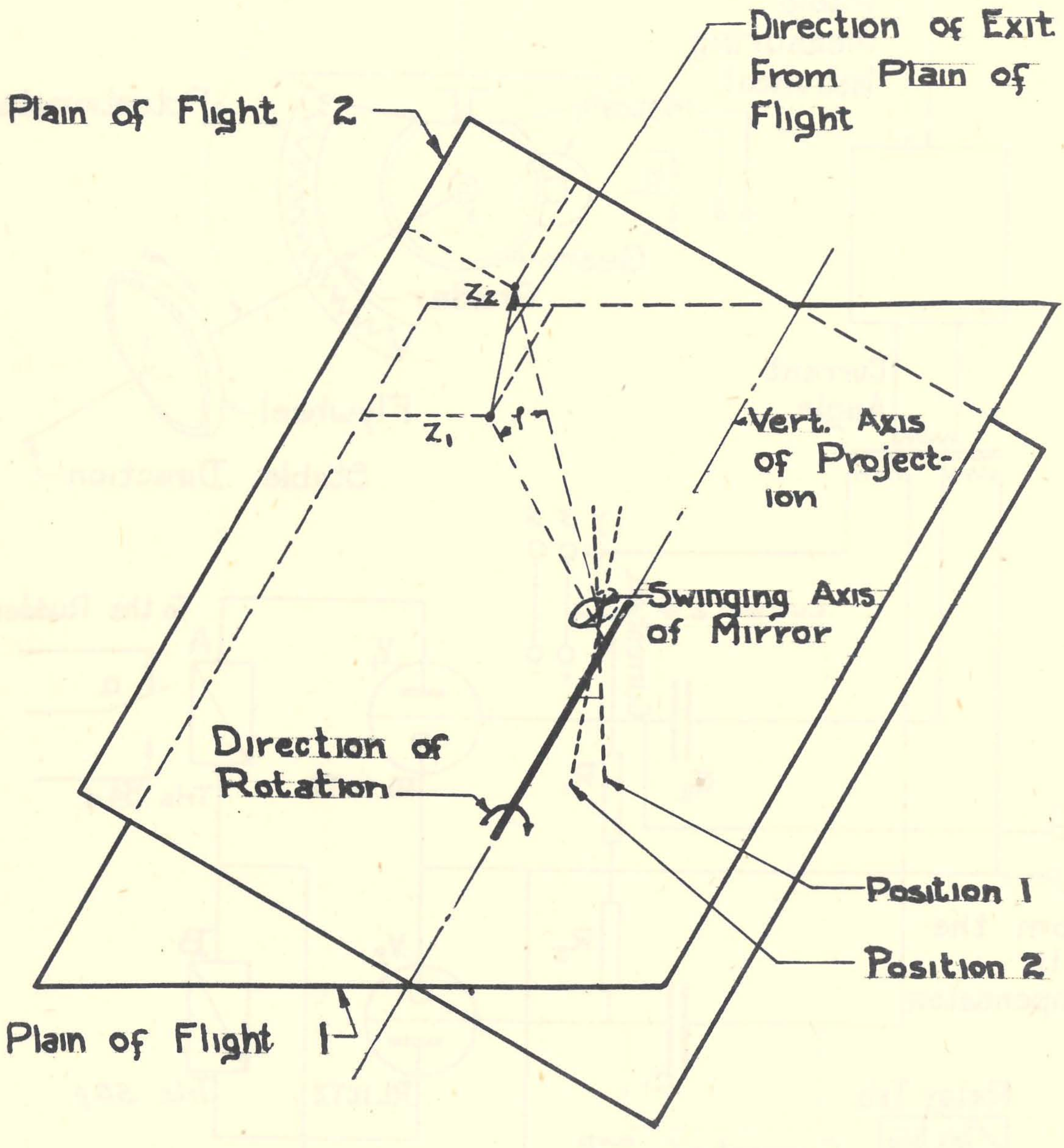
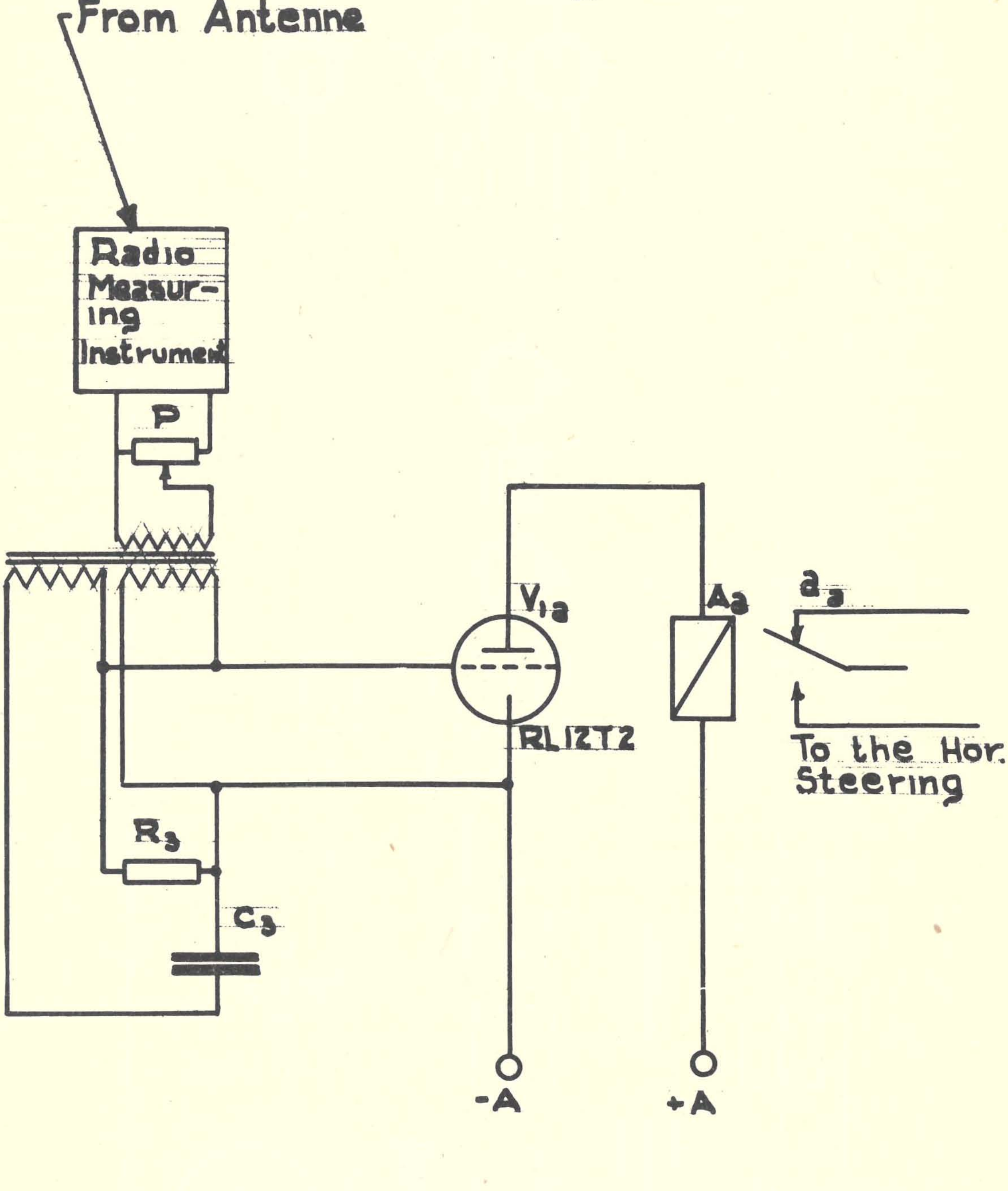

Direction of Exit
From Plain of
Flight
Plain of Flight 2
z_2
z_1
Vert. Axis
of Project-
ion
Swinging Axis
of Mirror
Direction of
Rotation
Position 1
Position 2
Plain of Flight 1

Fig 5


From Antenne
Radio Measuring Instrument
P
V_{1a}
RL12T2
A_a
a_a
To the Hor. Steering
R_3
C_3
-A
+A

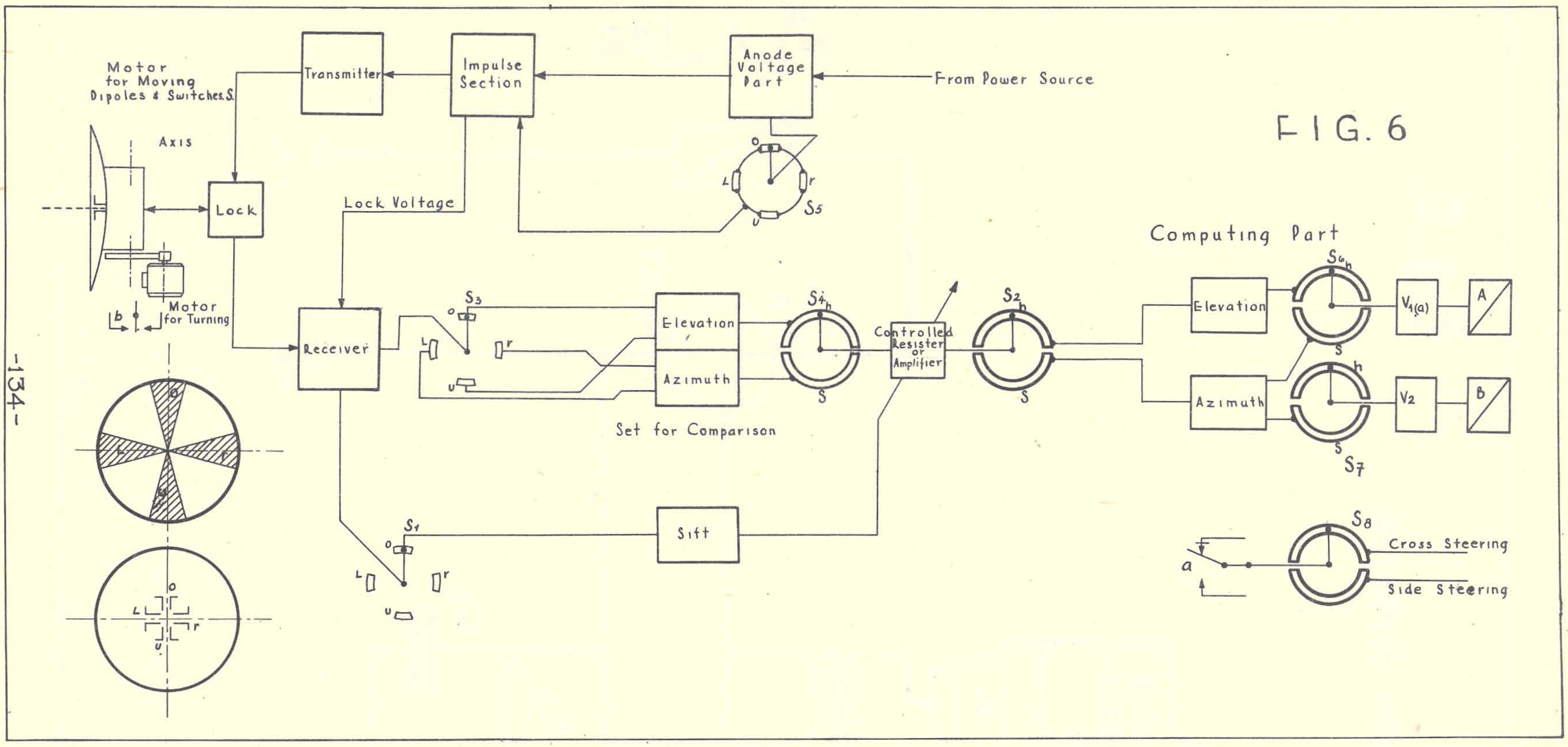

Motor
for Moving
Dipoles & Switches S.
Axis
Motor
for Turning
b
Transmitter
Lock
Impulse
Section
Anode
Voltage
Part
From Power Source
Lock Voltage
Receiver
S3
S5
o
r
L
u
Elevation
Azimuth
Set for Comparison
S4
h
S
Controlled
Resister
or
Amplifier
S2
Sift
S1
Computing Part
S6
S7
S8
V1(a)
V2
A
B
a
Cross Steering
Side Steering

FIG. 6

Simplified Diagram

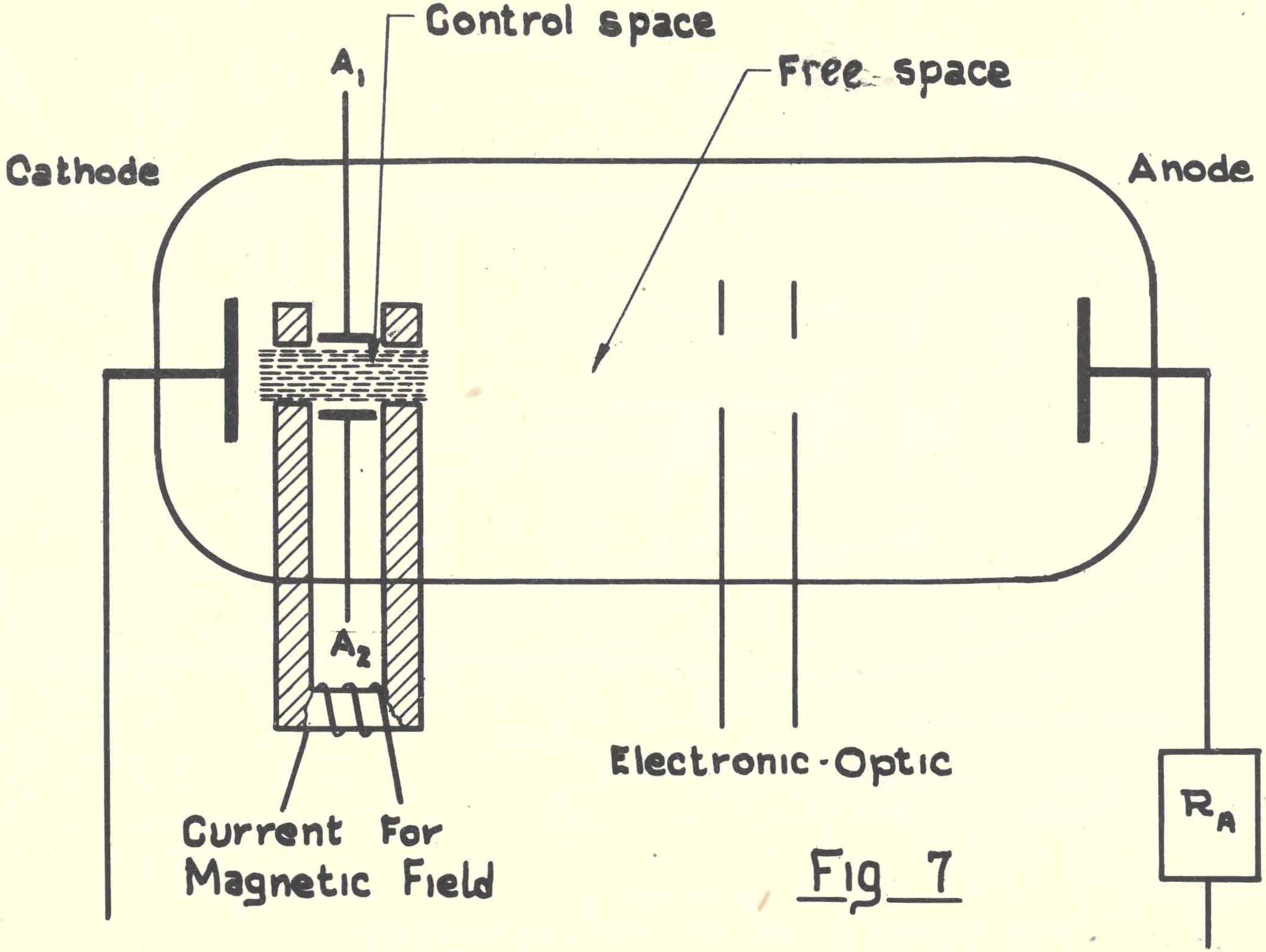
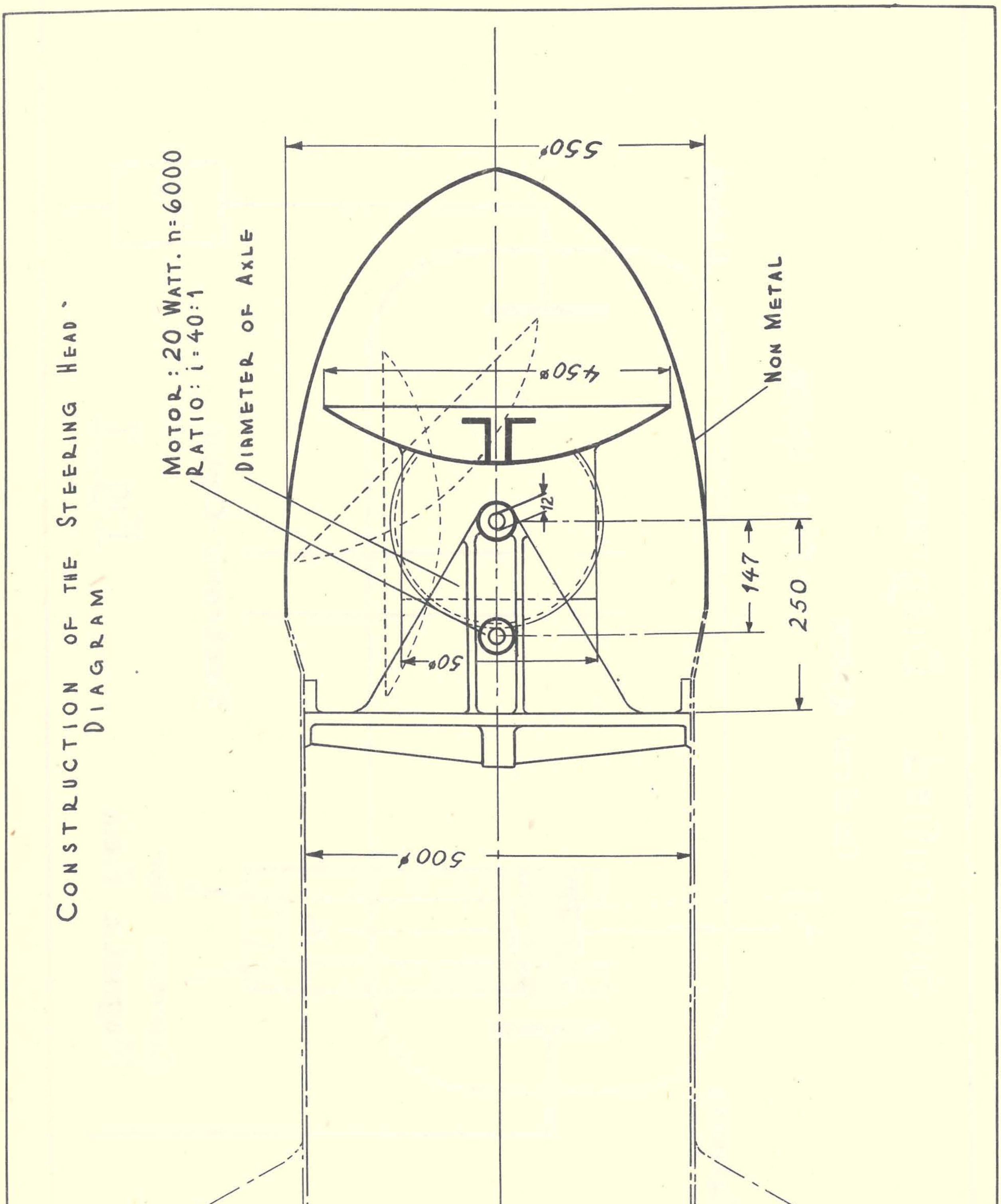


Fig 7


CONSTRUCTION OF THE STEERING HEAD - DIAGRAM
MOTOR: 20 WATT. n: 6000
RATIO: i: 40:1
DIAMETER OF AXLE
NON METAL
550φ
450φ
50φ
500φ
12
147
250

C. TELEVISION HOMING.

1. General Information :

In the development of a television homing device for HS-293 and for Wasserfall several basic research projects on television were undertaken, mostly by Fernseh, now located at Taufkirchen, but formerly of Berlin and evacuated to Sudeten, and finally to Taufkirchen. Since the development of a television homing device is dependent on this basic research, the main research projects are included in the following paragraphs.

2. Research Projects.

a. The Super Iconoscope LF-71 (Type IS 9)

In principle, this is similar to the super-iconoscopes known before the war, except that the mosaic is replaced by a secondary emitting surface of high resistance, so that changes produced at a point on its surface do not spread appreciably.

The picture is focussed by a 35 m.m. focus F/3.5 lens on to a photocathode measuring 10 m.m. square. A cathode of this small size is used so that a standard lens system can be utilized. A larger surface could have been used and, with a lens of the same F number, would have given greater sensitivity had this been required.

The photo surface consists of a thin film of antimony caesium, or of silver caesium if sensitivity in the infra-red region is required.

The electrons emitted from the back of this surface (which is at - 600 volts) are focussed by a combined electrostatic and magnetic lens system on to the secondary emitting surface. They cause secondary emission from this surface, thus building up a positive charge pattern on this surface, corresponding to the picture. This pattern measures about 50 m.m. square, a magnification of about five times being obtained in the electron lens.

The secondary emitting surface consists of a mica sheet covered on the front with a layer of magnesium oxide on which is evaporated a very thin layer of caseium. The back of the mica sheet is covered with a thin layer of silver, forming the signal plate. Dr. Behne has been asked to prepare a report detailing the methods of preparation of these surfaces.

The secondary electrons are collected by a ring placed a short distance in front of the secondary emitting surface and at a potential of + 10 to + 40 volts, the optimum voltage for each tube being found by experiment. Little trouble has been experienced due to secondaries falling back on other parts of the surface. The emission ratio is about

1 : 6 or 1 : 7.

The secondary emitting surface is scanned by a beam from an electron gun placed at 20 degrees to the tube axis. This gun is focussed and deflected magnetically and operates at 1000 volts. Geometrical distortion due to the angular offset of the gun is compensated by a small additional coil placed beyond the main deflecting coils and carrying the deflection current. This produces a non uniform field and, by adjustment of its position, distortion can be virtually eliminated.

It is claimed that this tube is ten times as sensitive as a standard inconscope despite the use of a smaller lens. 500 to 1000 lux are required for a good picture. The improved sensitivity is attributed to the following factors :-

(a) Saturated emission from the photo-surface.
(b) The secondary emission factor of the secondary emitting surface.
(c) The fact that the secondary emitting surface is continuous (with a mosaic only 30% to 50% of the area is used)
(d) Saturated emission from the secondary emitting surface.

The output of this tube is about 25/ua. lumen. A sensitivity of 2.5/ua/lumen is obtained in the infra-red region (0.86/u to 1.25/u using a silver caesian cathode and a ZeissU.G.6 filter.

Definition is quite adequate for a 441 line picture and more lines could probably be used. The ultimate limit of definition is determined by the size of the spot produced by the electron gun.

Tests have been carried using the camera in the infra-red region and considerably improved results have been experienced under conditions of light haze. These tests were carried out by Dr. Folsche at Einring who should be able to give full information. About 2000 super-iconoscopes were made by Fernseh, the production rate being about 20 per day. Most of these tubes have fallen into Russian hands.

b. <u>The "In Line" Iconoscope.</u>

In physical appearance this tube resembles a normal cathode ray tube. A normal electron gun is used, with electrostatic deflection and focus.

The electron beam scans a mosaic of silver globules on which a small amount of caesium has been evaporated. The mosaic is backed by a mica sheet, and on the other side of this sheet is a thin semi-transparent layer of tungsten,forming the signal plate. The light thus falls on the mosaic after passing through the tungsten layer and the mica sheet. These absorb about 50% of the light, so that the tube is about half as sensitive as a normal iconoscope.

This loss in sensitivity is compensated by simplicity of construction, by absence of distortion and by compactness.

The maximum definition is about 300 lines, being limited by the focus of the electron gun. This tube was designed for mass production, but only a few experimental models were made.

3. Television System for Guided Missiles.

This consists of two units (camera and transmitter) in the missile, and a further two circuits (receiver and indicator) in the controlling aircraft.

All units measure 7" x 7" x 14½". Only the camera and indicator were designed by Fernseh, the radio link being designed by another firm.

In the early models a 441 line interlaced picture was used, the picture frequency being 25 per second (frame frequency 50 per second). This utilized a sinusoidal master oscillator running at about 22 kilocycles. This was followed by a frequency halving stage to provide the line frequency (11 kc) and by three dividing stages (dividing by 7, 7 and 9 respectively) for the frame frequency. Subsequent models dispensed with the interlace and gave a 225 line picture, this change being made for the sake of simplicity and because the receiving cathode ray tube was only 13 cm. in diameter and was not good enough to do justice to higher definition. In this case the master oscillator ran at line frequency (11 kc) and was reduced to frame frequency by three blocking oscillator dividing stages, dividing by factors of 4, 7 and 8 respectively. The picture frequency was therefore 50 cycles.

The pick-up tube used is the super-iconoscope described above. In the early cameras an attempt was made to mount the optical lens on a platform stabilized by a free gyro, in order to stabilise the line of sight of the camera. This was eventually abandoned owing to frictional difficulties and instead, a gyro-stabilized spot of light was superimposed on the picture. This was, in practice, used merely to enable the missile to be headed in the right direction, if the target could not be distinguished in the early part of the flight, and was ignored as soon as the target became visible. While the Fernseh people agreed that it would have been preferable to stabilize the whole picture, it seemed that they did not fully appreciate the advantages of so doing, i.e. the reduction of the effects of drift and steering yaw.

The remainder of the camera follows normal practice, blanking and "blacker than black" line synchronising pulses being injected in the normal manner. The 225 line camera gives no frame synchronising signal, the framing being adjusted manually by the operator at the receiver.

The video amplifier has a gain of 10^4. Its frequency response is flat to 2.5 mc. and then falls to nearly zero at 4.5 mc. The noise output of the tube is considerably below the noise level of the first amplifier stage, so that the signal/noise ratio is improved by using a high load resistor on the signal plate. The frequency is corrected by the application of negative feedback.

Negative carrier modulation is employed (a bright signal reduces the carrier level) modulation being effected by varying the cathode potential of a diode shunted across the tuned circuit of the transmitting R.F. oscillator. It is claimed that this rather unusual method permits modulation as deep as 90% with negligible frequency modulation.

The R.F. oscillator is at a frequency of about 430 Mc. and has a power output of above 15 watts. The oscillator valve is a single triode type TU.50/1.

One point of practical interest is the method of stabilising the current in the iconoscope focussing coils. A valve stabilising circuit is employed, with a neon tube as a reference. The voltage of this neon is found to vary to some extent with temperature. To compensate for this, a resistance coil is wound round the neon tube so that it attains substantially the same temperature as the tube. Any temperature variations will have the effect, both of altering the neon voltage, and of altering the value of the resistance. This resistance is inserted at a suitable point in the stabilizer circuit, so that it compensates to a large extent for the variations of the neon.

The Camera is fitted with the following preset adjustments :-

(a) X Centering
(b) Y Centering
(c) Focus
(d) Beam Current
(e) Potential of iconoscope collecting ring.
(f) Line shading
(g) Frame shading.

The power consumption of the camera plus transmitter is 12 amps. at 24 volts. About 200 equipments were made and some are in the hands of CIC in Paris, though most are in Russian hands. The receiver and indicator are of fairly conventional design. As already mentioned there are no frame synchronising signals. The line signal is extracted and the fundamental component is filtered and applied to the suppressor grid of an L.C. oscillator running at the line frequency, thus pulling this oscillator into phase with the line synchronising signal. The oscillator is followed by dividing circuits, identical with those in the camera, which produced the frame signal. The frame signal is phased manually by the operator, and provided the line signals are received continuously the picture should stay accurately framed.

The line oscillators in the camera and in the indicator are designed to be very stable and are temperature compensated. They are both adjusted to oscillate at very nearly the same frequency. Thus, if the line signal is interrupted, due to jamming or other causes, there will only be a very slow shift of phase. This is intended to improve the resistance of the equipment to jamming.

The picture quality obtained would appear to be excellent. Some photographs have been obtained of the picture given by the 441 line interlaced equipment. These pictures were taken using the whole equipment, including the radio link, but a large, good quality receiving tube was used. The photographs indicate that the definition was about as good as can be obtained with a 441 line system.

THE TESTING OF THE FERNSEH TELEVISION EQUIPMENT FOR THE HS. 293

1. General

The D.F.S. have been concerned with the testing and installation of the Fernseh television in the HS. 293. Their work falls into three categories, testing the radio link, testing of the camera and testing of the complete missile.

2. The Radio Link

Much trouble has been experienced due to ground reflections providing a secondary transmission path between the missile and the aircraft. Early tests were carried out with the transmitter on the ground and the receiver in the aircraft, and these troubles did not arise. However, when air/air tests were started, the transmitter being carried in a second aircraft, ground reflections had the effect of producing "bars" on the television picture.

Englebrecht was of the opinion that this trouble was largely due to residual frequency modulation being present in the transmitter, although this frequency modulation was probably less then 500 Kc/s. This, however, appears to have been a subject of disagreement as Fernseh were of the opinion that frequency modulation of their transmitter was negligible and that the "bars" were due to changes in the path length difference between the direct and reflected rays. Englebrecht made a crystal controlled transmitter in order to prove his point, but it apparently never got to the stage of being air-tested.

Whatever the cause of the "bars" it appears to have been agreed that the best solution was to reduce the reflected signal as much as possible. Very extensive experimental work was carried out with a variety of aerial systems including an aerial with a very elaborate parabolic reflector on the receiving aircraft. Vertical polarisation was found to give less trouble due to reflections and very satisfactory results were eventually obtained by mounting a four-element Yagi aerial above the fuselage of the receiving aircraft (an HE.111) and by mounting a similar aerial aft of the tail of the HS. 293. The receiving aerial was gyro stabilized in azimuth giving the aircraft freedom of manoeuvre.

When the HS. 293 was close to the controlling aircraft, additional fading trouble was experienced due to the fairly sharp vertical polar diagram of the aerial on this aircraft and to the fact that the HS. 293 dropped rapidly soon after release. The picture became steadier, however, after the HS. 293 had been flying for a short while.

After the various troubles had been overcome, ranges of about 110 kms. were obtained using the standard 73 cm. link, the gain of each Yagi aerial being about 4.

An experimental link was made working on 3.5 metres. On one test a range of 263 kms. was obtained with the controlling aircraft at a height of 4,000 metres and the bomb at a height of 1,000 metres.

3. The Camera

Herr Lutz carried out some work on the spectral sensitivity of the Fernseh super-iconoscope. For this work he used an extremely good spectrometer which, using two interchangeable prisms, had a range of 1,500 angstroms to 45,000 angstroms. Unfortunately, this spectrometer was destroyed.

The infra-red iconoscope was found to peak in sensitivity at about 0.9 u and to have an upper limit of about 1.1 u. The blue iconoscope peaked in the blue/green region. Under twilight conditions, The blue tube was found to give a signal about three times as strong as that from the infra-red tube. About 100 lux was sufficient to give a just visible picture using a F/2.8 lens.

Although its sensitivity was rather poor, the infra-red tube was found to give improved contrast and gave a very remarkable improvement under conditions of light haze. On one particular occasion, the maximum range at which objects could be distinguished, using the blue camera, was 1.5 kms. The corresponding range with the infra-red camera was 45 kms. In thicker haze and fog, the infra-red camera gave little improvement.

In general it was found that improved contrast resulted from cutting out the blue components of the picture and a Shott OG.2 orange filter was found to give improved contrast when used with the blue camera, although it caused a three-fold reduction in the sensitivity of this camera.

One trouble experienced with the blue camera, has been due to the presence of ion-spots on the screen, which can easily be confused with the target under certain circumstances. These appeared to be absent in the infra-red tube, although this may have been due merely to more careful manufacture.

It is understood that the Fernseh television camera using the infra-red tube was also used in the robot tank.

4. Installation and Testing in the HS.293.

The camera was mounted in a fairing forward of the war-head while the transmitter and power pack was mounted in the fuselage immediately aft of the war-head. The Yagi aerial was mounted aft of the tail

The aerodynamics of the HS.293 were found to be rather unsuitable for use with television owing to the severe yawing and banking resulting from the application of control. An attempt was made to improve this by stabilizing the camera lens by linking it mechanically with "ears" projecting outside the fuselage, but it is believed this effected little improvement.

Dr. Englebrecht had witnessed the testing of seven HS.293's against a wrecked ship near Peenemunde. One of the seven hit the target, the others all falling short. Dr. Englebrecht is of the opinion that the operator was extremely bad and that with a good operator a large proportion of hits would have beem obtained. He was none the less of the opinion that this television equipment was wasted in the HS. 293, and had been advocating its use in the project "Beethoven" which was understood to be similar to the American "Weary Willie" project.

NOTES ON A VISIT TO THE FORSCHUNGSANSTELLE DER DEUTSCHE REICHSPOST AT AACH

Persons contacted: Dr. Wunderlich, Dr. Michealis and others.

1. Fernseh Television

The F.A.D.R. have been closely associated with Fernseh in the development of this equipment. They were in possession of a considerable number of the equipments and one camera was demonstrated. Picture quality was extremely good and it was noted that the receiving tube had remarkably good focus and brilliance. A complete HS. 293 fitted with the television equipment was also examined. One point of interest was that the Yagi aerial was fed from the end, not from the centre, as is the usual practice. A resonant feeder was used.

Television for Wasserfall

An interesting television camera of very compact design is being developed for Wasserfall. Apart from the iconoscope only nine valves are used.

The frame and line signal are produced on the ground at the receiver, the line frequency being 4,000 c/s. and the frame frequency 10 c/s. The line and frame signal are transmitted to the missile via a fifth tone channel in the E.230 control link. This channel is modulated with a 4,000 c/s. sine-wave, giving the line frequency, and the amplitude of this sine-wave is doubled for a period of 10 c/s., ten times per second, giving the frame frequency. In the missile a five-valve circuit extracts the line/frame signals and produces the time base waveforms for the iconoscope. This is a small in-line iconoscope developed by Telefunken using a semi-transparent mosaic, the signal plate consisting of a very thin layer of silver. It is very similar to the in-line iconoscope developed by Fernseh. The video from the iconoscope is amplified by a four-valve video amplifier about 800 Kc/s. wide and the output of this amplifier modulates a small 1 watt oscillator working in the region 500 - 600 Mc/s.

This arrangement has several distinct advantages. First the more complex parts of the line and frame circuits are on the ground and the synchronising signal passes from ground to air so that if the missile aerial has adequate gain backwards, jamming should have little effect on synchronisation. Also there is no need for the normally fairly complex circuits to add blanking and synchronising pulses to the video from the iconoscope, as this can be done on the ground.

The experimental camera was examined and was found to give reasonably good picture quality, although the 10 c/s. flicker was very objectionable.

D. HOMING DEVICE DEVELOPED BY DR.RAMBOWSKA

Person contacted: Dr. Rambowska

1. This target was not covered in great detail as it has been fully covered by previous investigators. However, the general principles of the device under developement are described below. The equipment is an optical homing device to direct a missile at an isolated target in the air or on the surface of the sea, the homing being effected onto a light contrast. The image of the target, onto which homing is to be effected, is focussed onto the screen of a super-iconoscope after being reflected from the circuits associated with the iconoscope so as to keep the target in the centre of the iconoscope screen. The angular position of the mirror is therefore a measure of the mis-alignment of the target from the centre line of the missile.

2. The iconoscope performs a spiral scan, the spiral containing about 50 turns, although a ring of only about 2 or 3 turns is sensitive at any one time. At the start of the flight of the missile, this ring covers a small area in the centre of the field of view of the iconoscope. Before the missile is fired, it is lined-up so that the target is in the centre of this circle. Under these conditions the mirror will oscillate so that the target moves from side to side of this circle; each time it touches the circle a signal is applied giving a control voltage to the mirror. The mirror therefore hunts over a small angle corresponding to the diameter of the circle. As the missile approaches the target the latter will subtend an angle larger than that corresponding to the diameter of the sensitive circle. The circle then enlarges so that it just encompasses the image of the target, which therefore stays in the centre of the field of view. The mis-alignment signals from the mirror are used to steer the missile.

3. The circular scan on the iconoscope is produced by two sine-waves in quadrature at a frequency of 5 Kc/s. The spiral is produced by modulating these sine-waves with a saw-tooth at 100 c/s. When the beam in the iconoscope scans the image of the target, a pulse is produced which de-sensitizes the receiving circuits for a period slightly less than the length of the scan saw-tooth. Thus the receiving circuits become sensitive again just before the beam is due to scan the target once more. In this way only a few turns of the scan are made sensitive, as mentioned above, so that the homer is made sensitive to the target on which it is locked and insensitive to other targets unless they are quite close to the target onto which homing is being effected. The pulse produced for scanning the target is amplified and is used to trigger a blocking oscillator which gives a lengthened pulse of constant amplitude lasting for about a quarter of a cycle at the sinusoidal scanning frequency. This pulse is then fed into two phase-sensitive detectors where it is mixed with the 5 Kc/s. scanning signals and D.C. voltages are obtained proportional to the X and Y co-ordinates

of the target. These voltages then work two small servo motors on the mirror which moves in such a way as to bring the target back to the centre of the screen.

4. In order to stabilize the missile, Dr. Rambowska believes that it will be necessary to obtain the first differential derivitive of the mis-alignment voltage which he proposed to obtain by differentiating the voltage obtained from potentiometers attached to the mirror. He claimed to have ideas about methods of effecting predicted homing, but when this was further investigated, it appeared to consist more of a desire to how we would effect it. He has been asked to write a short note on how he would effect predicted homing.

E. MESSINAGERÄT

1. A description of the Messina Gerät was given under Wasserfall, since this homing device was designed primarily for use in the Wasserfall project, however, the same description is included here for persons primarily interested in homing devices.

2. Messina was an Infra-Red homing device which began to operate 3 or 4 Km. from the target. Because of the small field of view of the "eye" (±3 degrees on a preferred model) it was necessary to point the eye on the target at the beginning of the operating region. This was done by "Krucke" A or B described below. The radiation from the target was modulated by a disc on which strips were blacked out so as to produce a frequency modulated square wave, the frequency excursion of which was a linear function of the angular target misalignment. The polar angle of the target was determined from the phase of the square wave. The square wave was limited and passed through a discriminator circuit, the output from which was a sine wave whose amplitude was proportional to the radial error of the target and the phase to its azimuth error. It was proposed to stabilize the eye so that it maintained a constant direction in space. In this way a collision course should be obtained.

3. The following information was obtained on the "Messina Gerät" by interviewing Dr. Weiss. Dr. Weiss worked on the design of the Infra-Red homing eye. The first idea was to use an eye which was mounted rigidly along the axis of the projectile and which gave proportional indication of target misalignment off this axis. This method suffered from two disadvantages. Firstly, that the pitch and yaw of the missile gave false indications of the angle between the tangent to the flight path and the direction of the target, and secondly, that if a predicted collision course was being flown, the direction of the target might make a large angle with the axis of the eye, this necessitating a large field of view and consequently a small range sensitivity. It was, therefore, decided to use an eye mounted on a stabalized platform which was so steered during the initial ground control of the missile, that the eye looked always along the line of sight, and therefore at the target. This was to be done by means of the "Krücke Gerät" for which two forms had been suggested. In one scheme the eye was rotated on the platform by signals from a backward looking receiver which D/Fed a ground transmitter, and in the other scheme the eye was turned by signals from the ground by an amount which was determined from a measurement of the rocket direction. In either case, when the missile came within the operating range of the eye, control was handed over to it and from then on it remained with its axis looking in a direction fixed in space. The inaccuracy of the "Krücke Gerät" in pointing the eye would lead to and initial misalignment (E) of the target with respect to the eye axis being measured. This was used to produce an angular motion of the rudders B such that

$$B = f(E)$$

The ideal trajecory would be onefor which E = 0, this leading, in the case of a straight flying target, to a straight line collision course and in the case of a non-linear target motion to a sideways acceleration of the missile which was not greater than the sideways acceleration of the target. In order to produce a stable homing trajectory the function f(E) had to contain other time derivatives of (E) but its form had not been determined.

4. The homing device consisted of a mirror with a rotating shutter at the forms. The radiation passing through the shutter was diffused onto the surface of an Elac Infra-Red cell, the output of which was amplified. Weiss devised a shutter with strips which gave square wa ve chopping of the radiation, the chopping being at constant frequency for an image on the axis, but having an increasing frequency modulation deviation for a source at an increasing angular misalignment. The output of the amplifier was therefore connected to a frequency discriminator which gave a sine-wave output whose amplitude was proportional to the misalignment and whose phase, on comparison with a reference commutator gave the phase of this misalignment with respect to the eye axis. The use of frequency modulation was said to give the direction of the brightest spot in a distributed target, but this does not appear to be true if normal amplitude limiting is carried out before passing the signal into the discriminator. This method does not, however, seem to bad a very simple circuit for sorting out proportional misalignment. The beam width necessary for a homing device used in this manner was determined by the accuracy of the "Krücke Gerät" and also by how far the manoeverability of the missile could keep E = 0. Beam widths actually used were from 6 degrees to 12 degrees. Weiss said he had a scheme for using a much narrower beam but he refused to discuss it. It is presumed that he was considering a locked follow eye with initial scanning in order to find the target.

4- RESEARCH RELATED TO GUIDED MISSILE WORK

A. GENERAL INFORMATION

The object of this section of the report is to cover those basic research projects which were encountered by CIOS team 367 whose solutions can be applied to Guided Missile work. The following contains information gained from reports written for other Technical Investigation Teams, information gained from interviewing German Scientists and from Translations of German Documents. It is felt that the following information is very far from complete, but in most cases no other reports are known to exist containing the same information.

B. REPORT ON THE INTERROGATION OF DR.KASPER OF AEG

Organization

The A.E.G. were engaged on research work for the German National Council of Research.

Prof. Gladenbeck was the leader of the Fernmeldwesen Division of the A.E.G. which was responsible for research on control of missiles and on radio and infra-red homing aids and proximity fuses. Prof. Gladenbeck was formerly president of the Reichpost Institüt and also of the Vorsuchstelle für Technische Forschung which did electrotechnical research for the Ministerium für Rustung und Kriegsproduktion. He is said to be in Hamburg.

Dr. Kasper was a group leader in Prof. Gladenbeck's division and was responsible for physical and chemical work on infra-red cells and also for devising methods for their mass production. This work was done in Konstanz.

Prof. Gudden of the Feuerleitwesen Kommission in Prague was in charge of the approval testing of the Konstanz production cells

Dr. Orthuber was in charge of the group at Neustadt-bei-Coburg which worked on the application of infra-red cells to the control of guided missiles. The optical part of this work was done in connection with Zeiss at Jena. There is said to be equipment and samples of these devices at Neustadt.

Dr. Hilgers was also working at Neustadt on similar devices.

Prof. Petersen was the leader of the Feuerleitwasen Kommission and organized measurements on the intensity of the infra-red radiation from various types of aircraft. It was found that the production cells when used in a Zeiss mirror system having an aperture of 25 cms. would give useful signals on a Lancaster at ranges of 2-3 Kms.

Work by Dr. Kasper

Dr. Kasper was originally engaged on investigation of the Photoconductivity of Lead sulphide crystals. The lattice structure of the crystal is cubic as in the NaCI crystal structure. It was found that the pure crystal has no photoconductive properties. Experiments were then made with impure crystals having either an excess of lead or of sulphur ions. In fact, an excess of one ion represents a state where there is a deficit of the other ion, leaving holes in the lattice, since the ionic packing is so tight that there is no room for the insertion of extra ions. The electronic balance is made up in either case by the neighboring ions (not the ones diagonally opposite) having single instead of double charges. With these imperfect crystals it was found that the ones having an excess of sulphur had slight photoconductive properties, but the ones having an excess of lead had none. The photoeffect was found to be greatly enhanced if the singly charged sulphur ions next to the space left by the missing lead ion were replaced by oxygen ions. The explanation for this phenomenon is that while an electron may, in the field distortion produced by the imperfection of the crystal, on the absorption of a quantum of infra-red radiation, pass from a sulphur ion to a lead ion, the probable recombination time is so short that photoconductivity can not take place. In the presence of oxygen ions, however, the electron may pass back from the lead ion to an oxygen ion which is then in a meta-stable state with a much longer life. There is then a much larger probability that the field conditions will be restored by conduction of electrons in the presence of an applied field.

The preparation of lead sulphide crystals having this property was carried out by mixing solutions of lead acetate and thio-urea, using a slight excess of the latter, the concentrations being such the resulting lead sulphide was in very slightly super-saturated solution. Crystals then formed slowly and were deposited on the glass surface later to be used for making the complete cell. The formation of very large crystals, which are necessary if contact noise is to be avoided, depends on the use of only slightly super-saturated solutions, and under these conditions, the first small crystal nuclei are produced in small regions of larger concentration caused by statistic variations. It was found that the already small probability of the formation of a crystal nucleus was very much decreased by the presence of copper ions so that even one part in 10^7 of copper was sufficient to inhibit crystalisation completely. It was therefore necessary to use very pure reagents and to use water distilled from glass vessels rather than from copper ones.

The lead sulphide deposit was allowed to form a thickness of 2-3 μ and was then removed, washed and dried. It was then heated for half an hour at 100°C. It was shewn by X-ray measurements that the lattice constant changed as a result of this baking process. A graph was plotted shewing the lattice constant as a function of the baking temperature, the period of baking being the same in each case, It was shown that the lattice constant first increases as the baking temperature is increased, then falls to a minimum, rises to a second maximum and then falls to the normal value for the lead sulphide crystal. At the same time the photosensitivity rises from zero to a sharp maximum which is coincident with the minimum in the lattice constant at 100° C.

The sensitivity of lead sulphide cells to infra-red radiation was measured at different frequencies using a spectrometer, Since at short wavelengths the effect of a single quantum of energy is the same independent of its size, the response of the cell at different frequencies, for equal amounts of energy falling on it, rises hyperbolically as the wavelength is increased. At the wavelength of 3.0 microns the energy per quantum ceases to be sufficient to cause a transition and sensitivity falls to zero at 3.5 microns. Sensitivity is increased by cooling the cell surface with solid CO_2. For the best research cells a sensitivity of 0.035 microwatts total energy falling on a $1cm^2$ cell from a black body at 300°C and using a band width of 1Kc/s was obtained. The production cells gave a figure of 0.15 microwatt sensitivity under the same conditions. For uncooled cells, which were useful for infrared signalling purposes the sensitivity figure was ten times worse. Different methods had to be used for the best production of cells of either type.

A large amount of work was done to investigate the cause of cell noise. At least five kinds of noise were differentiated:- thermal noise, contact noise, work function noise, dissociation noise and lattice defect noise. The first of these is the kind found in all resistive conductors. The second is caused by heating effects at points of contact between different crystals. The third arises from statistical changes of electron density in the region of the potential barrier caused by the differing work functions of the lead sulphide and the material used for making contact to the cell. The fourth is caused by thermal deionisation changes in the crystal, and the fifth is caused by lattice imperfections due to impurities. The magnitude of the noise produced by the cell is reduced as far as possible by making the crystal size large and by using a contact material having a work function as nearly as possible equal to that of the lead sulphide. Carbon was found to be the best substance, but it could not be easily deposited in mass production and so platinum was used as the next best.

The variation of signal to noise ratio with frequency of an intermittent illumination was also investigated. The signal itself remained substantially unaltered up to a frequency of 300c/s and then fell off so that it was only 15% of its original value at 1000c/s. The time constants for uncooled cells are smaller, the output falling only above 1000c/s. The total noise level in a cooled cell is about three times the thermal noise, but as the frequency is increased, the band width remaining constant, the noise falls to the thermal noise level. The signal to noise ratio, therefore, does not fall so rapidly owing to this compensating effect.

Applications

Kasper was not very familiar with the work that was being done by the other A.E.G. people on the applications of his cells to guided missiles. He knew that a system was being designed by Dr. Orthuber to provide the ground to air flak rockets Schmetterling and Wasserfall with homing heads and that a 25 cm. mirror was to be used which focussed an image on a pair of rotating shutters, each with two sets of silvered segments, which interrupted the radiation at frequencies of 350, 450, 550 and 650c/s. The amplifier used had a band width of 70-80c/s. After the shutter a lithium fluoride lens, the back surface of which was in contact with the cell window, was used to spread the radiation from each point on the field of view over the whole surface of the cell. This window was made from a thin (0.6mm) disc of Duran glass, accurately flat, which was then fused to the outer tube of the cell. It was stated that any type of glass would serve this purpose since, with such a small thincknes the transmission loss was not great. In order to avoid vibration noise the leads were encased in glass, and the inside of the inner tubes was silvered so that vibration of the solid CO_2 filling, having a large dielectric constant, did not cause variation of lead capacity.

Kasper did some research on the preparation of the silvered shutters. In order to reduce shutter noise the edges of the segments must be sharp and accurately true. A method of coating the plates with a collodion photographic emulsion and then exposing to an image of an accurately drawn picture and developing was first tried, but it was found that such shutters only gave about 10% modulation of the beam since the best photographic blacks transmit above 2 microns, and collodion only transmits 20%. The method finally adopted was as follows:- The disc was first dipped in a solution of potassium dichromate in collodion and then centrifuged so that only a thin film of collodion remained. The image of the large scale picture was focussed on it and it was illuminated with ultra-violet light for a fraction of a second. The disc was then washed with water and the unfixed $K_2Cr_2O_7$ was washed out. The remaining $K_2Cr_2O_7$ was fixed by a second illumination of the whole plate with ultr-violet. Silver was then deposited chemically over the whole plate and the latter was then washed in chromesulphuric acid which dissolved away the silver which was on the portion of the disc not covered by the chromate. This method produced a good clean shutter.

Similar discs were made for a system of Dr. Hilgers. These are the ones which were found at Neubleicherode and are described in the report on WASSERFALL. The glass used was SF6 which is a lead glass.

Dr. Kaspar had done a little work on lead selenide cells, which were used, cooled in liquid air. The response of these cells was good up to 4-5 microns. He also mentioned that Kutscher at Elac and Görlich at Zeiss were working on similar PbS and PbSe cells.

Reports

Dr. Kaspars papers are said to be at Konstanz, but he has written reports for Dr. Brode of US and Prof. Mureau of France.

C. REPORT ON THE INTERROGATION OF DR. RUDAT OF A.E.G. [redacted]

Organization

Dr. Rudat was in the same division of the A.E.G. as Dr. Kaspar, and did work on a pulsed optical detection system and also on very long delay fuses.

Optical Detectors

The optical system of detection of short range targets developed by Dr. Rudat used the same principle of receiption of reflected pulses as used in radar. In this case the transmitter consisted of a discharge tube filled with either air or argon mixed with CO_2 at a pressure of 3-4 atmospheres. The electrodes were of tungsten, 3mm in diameter, with a gap of from 3 to 10mm depending on the particular application, and with ends of somewhat elliptical shape, the latter being said to improve the life. The discharge tube was connected to a condenser/resistance/H.T, supply circuit, the condenser having a capacity of 0.1mf and a very small series inductance, and the H.T. being of the order of 50,000 candles.

The receiver was a caesium photocell whose output was connected to a three or four stage amplifier using EF 14 valves. These were found to be both suitable for pulse amplification and economical to run. The transconductance is 15ma/volt. The receiver was made insensitive during the transmitter pulse and again depending on the particular application, could be made to receive the light reflected from a target after any determined time lag by means of a stroke pulse.

The applications for this equipment were:-

(1) For blowing up bridges. The equipment was mounted on a raft which then floated downstream. An argon/carbon dioxide filling was used in the transmitter in conjunction with a short infra-red filter. A low pulse recurrence rate was used and the receiver had a low gain. When a reflected impulse was received from the bridge the explosion in the

raft was detonated.

(2) With high speed fighter aircraft the time available for firing the guns when passing within range of a bomber is very small and some method of automatic firing of the guns was considered to be necessary. An optical system with a 1000c/s recurrence frequency was used. For daylight working, a blue filter was used to cut out the infra-red reflection form clouds, while for night working a short infra-red filter was used. The beam width used was between 1 and 2°, this being fixed by the spark gap width. The field strength is independent of the spark length since the intrinsic brightness is roughly constant. The life of the gap is about 100 hours running at a voltage of 5000 and at a recurrence frequency of 1000c/s.

The same principle was used for a proximity fuse. In this equipment an annular lens was used which produced a narrow sideways-looking beam. When a missile bearing the proximity fuse flew past a target the reflected signals provided a response in the receiver.

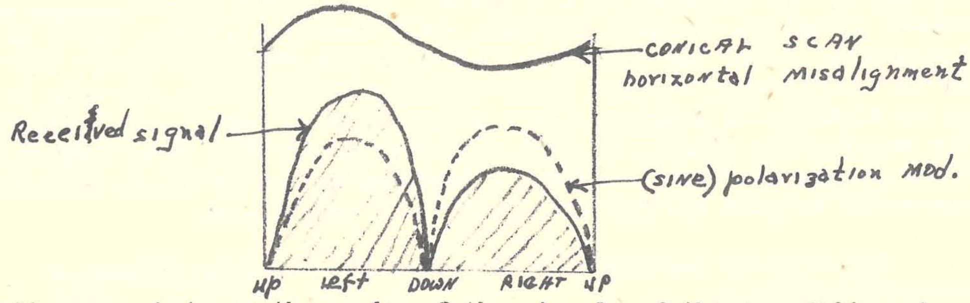
Rudat also worked on long delay fuses. One type used the slow evolution of gas formed by electrolysis of KOH solution. The increase of pressure in a small metal cell expanded the cell walls and made relay contacts. The cell was constructed from a thick brass ring, and the sides were of thin steel with a depression in each so that as the pressure increased they snapped out. The leads to the cell were brought in through an insulating plate and wrapped in silk and fibre. The latter was soaked in pure potassium hydroxide solution. Metallic impurities had to be avoided since they gave deposition of metal on the cathode without gas formation. The fibre was encased in a polyvinyl chloride plastic sheath. The contacts were made by light metal rods which were pushed out by the sides of the cell and pierced metal foil discs. The whole equipment had to stand a shock of 2000g on impact, and this was accomplished by making the fixed parts as strong as possible, and the moving parts as light as possible. The delay time was of the order of 100 hours.

D. RADIO CONTROL OF V-2

The automatic guiding of V-2 was by means of a conically scanning beam from a Wurtzburg antenna. This had a rotating polarisation so that when the beam was pointing upwards, the polarisation was horizontal. A C.W. transmission was used with tone modulation of two different frequencies one for the left hand and one for the right hand side of the scan. The missile had a receiver with an aerial polarised in the plane of flight.

The Würtzburg was sited in the plane of flight and about 10km back from the firing point so that the latter part of the controllable trajectory was at a nearly constant angle of elevation from the radio station. The Wurtzburg aerial elevation was programmed automatically so that it followed in the vertical plane the predicted course of the projectile. Furthermore, by repeating back the received signals to the ground, small vertical misalignments of the beam in the vertical plane could be measured and the elevation of the aerial was automatically corrected.

In the horizontal plane, the aerial was lined up accurately in the direction of the target. If the missile had a small horizontal error, the signal at the receiver appeared thus:-



The difference between the peaks of the signals of the two different modulation frequencies was proportional, in the absence of a vertical misalignment, the angular error in the horizontal plane. The two signals were therefore filtered in the receiver, peak rectified separately, and the resulting voltages were then applied, through a differential circuit to the "Mischgerät", The gain of the overall circuit was varied automatically, through a clockwork device so that the increasing range was taken into account, and the correction applied was proportional to the horizontal distance off the centre of the beam.

E. CONTROLLING OF THE FUSING OF THE HS-293 BY MEANS OF RADAR. (TRANSLATION)

Remote control rocket attacks on close bomber formations is only of advantage when the guided missile is being exploded at shortest possible distance. Besides the difficulty of correct steering of the HS-293, we also have the problem of proper fuzing at the most advantageous point. At first, it was thought that besides the launching plane, a second plane should follow the enemy formation which tracks the flying missile into the bomber formation, will set off the explosion. This system did not work out. Due to enemy fighter attacks, this steering plane was not able to observe the missile constantly; besides this, the use of the second plane makes this system rather uneconomic. Therefore, a suggestion was made to fuse the rocket by means of radar. It was suggested that the Neptun-R-Gerät which can easily compute range at an angle of 50 degrees. If this antenna is built into the nose of the laughing aircraft and the launching aircraft will stay from two to three km away from the bomber formation in order to avoid the loss of the plane, then we will find on our scope of the Neptun set, a primary pulse which will represent the formation of our scope. When the HS-293 is launched, a small pulse will be seen on the scope with a decreasing amplitude which will move towards the primary pulses which have been described above. The observer in the launching aircraft will fuse the flying rocket at that instant when the small pulse is covered entirely by the primary pulses.

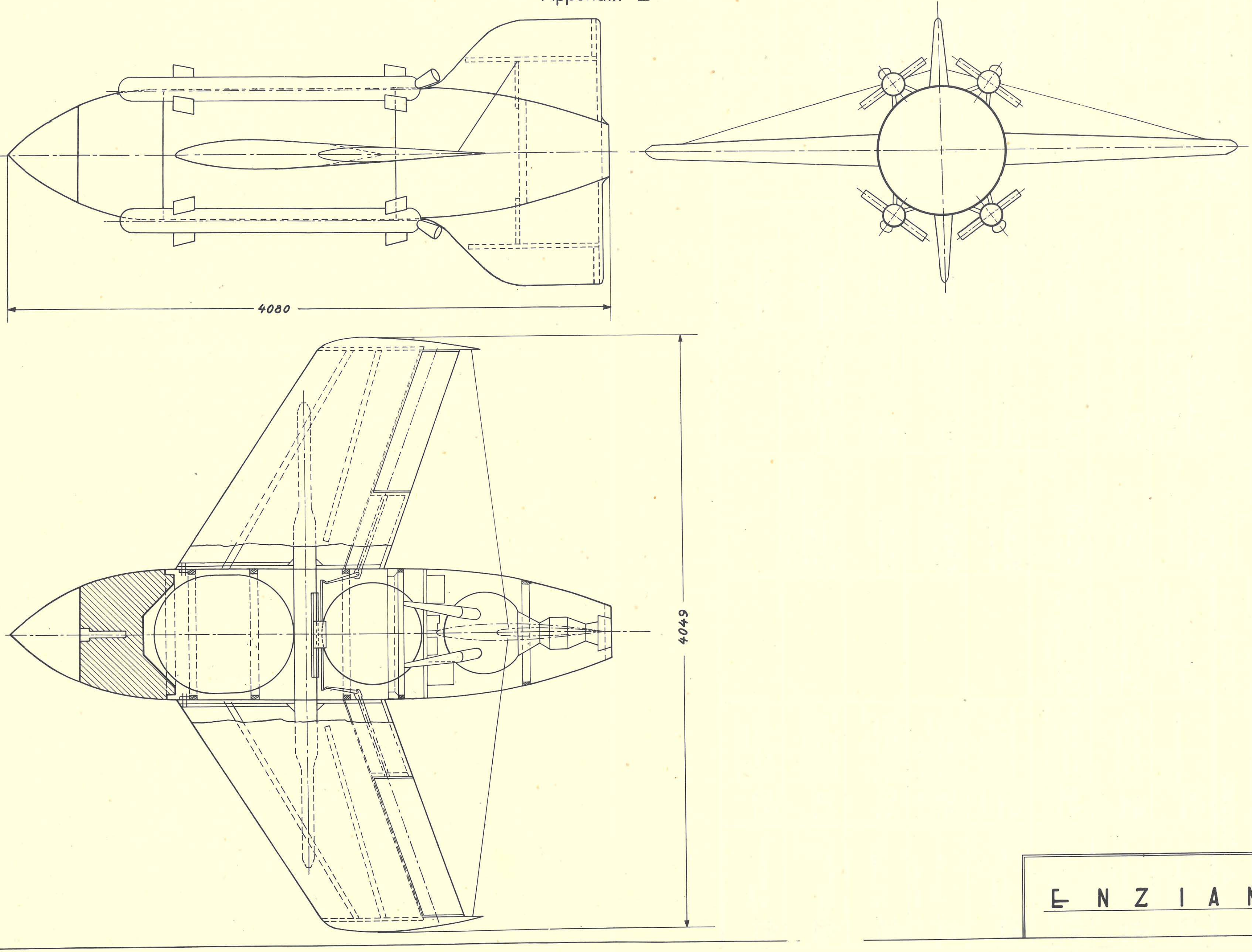
Experiments have shown that this type of fusing is possible. It is however very important that the fusing is done at the very exact instant of the covering of the pulses. The HS-293 flies through the bomber formation in about 25-secs. which means an average apeed of 100-m/sec. Since the effective radius of the HS-293 is 15-m, the fusing is to be done with no more than ± 0.1 sec delay, which can only be done by an experienced operator after a long time of training. Therefore, the experiments station in charge of trying out this radar system of fusing, suggested constructing a training apparatus which will enable operators to gain the necessary amount of experience.

The rest of the Document describes the training Device, A Modified Neptun R.

APPENDIX I

A Weapons		V W'pns	Henschel	X Weapons	Flak & Gnd G/M's	Unguided Missiles	Developments
A0 First Model of V-2.	**A8** A-9 Development Model.	**V1** Ground to ground Jet propelled-aerodynamic stabilized projectile.	**HS-293** Models A thru I, see Technical Analysis.	**X-1 or F-X** also known as **PC 1400 - X** Radio or Wire.	**Enzian** E-4 Models I, II, III, IV & V. Technical Analysis.	**Tiafun** see Technical Report.	**MV-1**
A1 V-2 Development// Failure.	**A9** V-2 or A-4 with wings for range of 600 Meters.	**V2** Ground to ground rocket propelled projectile. Length: 40 Ft/Wt:	**HS-294** Models A & H see Technical Analysis.	**X-2** Experimental model - [illegible] velocity X-1. Only [illegible] be built.	**Wasserfall C-2** See Technical Analysis.	**Rheinbote** Four-stage ground to ground rocket.	**ME-5**
A2 V-2 Development// Failure.	**A10** Development of additional take-off unit for A-9 or V-2.	**V3** Larger V-1 with incendiary warhead.	**HS-295** See Technical Analysis.	**X-3** Supersonic version of X-2 and Y-2.	**Rheintochter** Models I & III, supersonic ground to air missile.	**R100 BS** Air to air rocket-assisted bomb.	**Kurt 1 & 2**
A3 V-2 Development// Failure.	**A11** Development model of A-9 & A-10 for long-range (3500 Mi).		**HS-296** See Technical Analysis.	**X-4** Air to air wire-controlled glide-bomb.	**Komet 2** See Technical Analysis.		**Rochen**
A4 Later known as V-2. V-2 Development.	**A12** Development model of A-9 & A-10 for long-range (3500 Mi).		**HS-297** Forerunner to HS-117. See Technical Analysis.	**X-5** Larger model of X-3 (2½ Ton) for use [illegible] heavy armor.	**Feuerlilie** Models F-25 & F-55, radio-controlled, fin stabilized, flak rocket.		**L-Series** L-2, L-10, L-11, L-30, L-40, L-50, LT-950: Aerial Torpedoes.
A5 Small V-2 Model// First success.	**A13** Development model of A-9 and A-10 for long-range (3500 Mi).		**HS-298** See Technical Analysis.	**X-6** [illegible] as X-5 with warhead designed to produce blast.	**BV-143** Aerial torpedo glider (Blohm & Voss).		**Pirat-H**
A6 A-9 Development Model.	**A14** Development model of A-9 and A-10 for long-range (3500 Mi).		**HS-117 Schmetterling** Models A-1, A-2 -C & H See Technical Analysis.	**X-7** "Rotkäppchen" Anti-tank weapon, 10 Kg warhead.	**BV-246** F-1 to F-4 Glide bombs (Blohm & Voss).		**Hecht**
A7 A-9 Development Model.	**A15** 3500 Mile range V-2 with glide wings (Never constructed).				**Peter - X**		

Appendix II



ENZIAN

Appendix III

Komet 2

Appendix IV

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