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INVESTIGATION OF ROCKET RESEARCH

ELEKTROMECHANISCHE WERKE G.M.B.H.

SECRET

COMBINED INTELLIGENCE OBJECTIVES

SUB-COMMITTEE

SECRET

INVESTIGATION OF ROCKET RESEARCH
AT
ELEKTROMECHANISCHE WERKE G.m.b.H.
Evacuated from Peenemunde in early 1945

Reported by

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CIOS Item Nos. 4 and 6
Rockets and Rocket Fuels
Directed Missiles

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

SECRET

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INVESTIGATION OF ROCKET RESEARCH
AT
ELEKTROMECHANISCHE WERKE G.m.b.H.

Part I. Target Identity

The target is identified as Elektromechanische Werke G.m.b.H. evacuated from Peenemunde in early 1945 chiefly to the region surrounding Bleicherode (5127N 1036E). This organization was known as Heimst Artillerie Park 11 prior to 1 August 1944, when it was changed to the above name, Elektromechanische Werke. Its principal activity has been the research, development, and design of liquid propellant rockets, its best known development being the so-called V-2.

Part II. Investigation Synopsis

Mr. E. H. Hull and Major R. B. Staver first went to Bleicherode on 13 May to follow up leads from Lt. Hochmuth and Lt. Martin, both U. S. Ordnance Department, which they obtained one to two weeks previously. Other investigations prevented earlier exploitation of this target area which at this time was not fully identified. However, the recent presence of Professor von Braun and other important personages from Peenemunde, together with the continuing presence of Directors Fleischer and Rees indicated important activity in this region. On the first day it was learned that the Elektromechanische Werke had been recently directed by the Reichminister for Armament Production and the Chief of the Heereswaffenamt (Army Ordnance Office) to evacuate to the vicinity of Bleicherode. Much equipment was disposed about this vicinity in as many as nineteen different towns, and in some instances, in several places within a single town. These targets, plus interrogations, led to additional targets, making it impossible for the aforementioned persons to cover personally all places of interest. About this same time Colonel Cook's CIOS Team No. 163 happened upon the same target area and with the help of local Ordnance transport assisted in the evacuation of several items to a collecting point in Nordhausen. Lts. Ruwell and Harker, and Ensign Gnau, of Nav Tec Mis Eu, all known to the undersigned, appeared in Nordhausen about this time and were enlisted to help with the investigations material evacuation, and the interrogations. Also Lt. Hochmuth of Ordnance Technical Intelligence Team No. 1 moved to Nordhausen to assist this undertaking.

Probably most of the equipment in the vicinity of this target arrived by rail directly from Peenemunde. The balance was being transported by boat through the Eastern Sea to Lubeck and thence by canal

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boat to the south and up the Elbe to either Barby or Schonebeck, where it was to be transferred by rail. From 8 to 14 canal boats are reported to have arrived at the last named towns. The balance of 15 to 25 boats are believed to be strewn down the Elbe canal as far as Lubeck. A systematic search has been made of all known dispersal points in the Bleicherode area, and samples of important equipment and documents have been evacuated.

Interrogations of Fleischer, Commercial Director of Elektromechanische Werke, and Rees, Fabrication Director, provided much useful information. On 15 May, Mr. Hull and Major Staver accompanied by Dirs. Fleischer and Rees visited the "Prufstand" of Mittlewerke located between Schmiedebach and Lehesten, about 30 to 35 km south of Saalfeld. (This target is discussed in body of report.) By chance, Walter Riedel III, Director of Development and Construction for Elektromechanische Werke, was located in the prison at Saalfeld where he was being held on the charge of being the inventor of a bacteria bomb. He was released to the custody of Major Staver and brought to Bleicherode for interrogation. Dipl. Ing. Grottrupp, an assistant to Director Steinhoff in the Electrical Control Department, was located in a nearby town and interrogated. On 16 May W. Hausz arrived at Nordhausen to investigate electronic control of missiles. The above mentioned people plus a Mr. Gengelbach, a specialist in ground controls for the A-4, accompanied various field trips to provide information on the numerous findings. During this investigation, interest has centered principally about the latest important project of Elektromechanische Werke, called "Wasserfall", a 3600 kg flak rocket steered from the ground. Should the Pacific War last sufficiently long, such a missle might be employed against the Japanese.

Part III. History

In 1931 and 1932 the testing of small rockets in Germany centered chiefly around a small test ground outside of Berlin. Vallier (killed during a test in 1932) was one of the chief men to propose propelling missiles and people through space by gas jet reaction. Other important people at this time were Opel and Nebel (actually publicity man for the German rocket society). At this time Professor Goddard was held in high repute by all the German rocket enthusiastics. According to Mr. Rees, about this time Vallier had a little rocket model (non-flying) believed to have been called A-1. Rees believed that the A-2 was on paper in 1931, but was neither made nor tested.

About 1932 the Heereswaffenant (Army Ordnance Department) became interested in this group and set up a branch with only a code number for a name. All other groups were forbidden to develop rockets. The chief of the Heereswaffenant, General Becker (also Director of the Technische Hoschule in Berlin) collected several important people for this new section. Some of these were as follows:

a. Wernher von Braun, who was still a student working on his thesis of the fundamental theory of rockets.

b. Vallier.

c. Riedel I, for rocket construction.

d. Riedel II, for rocket testing.

Captain Dornberger was appointed military chief of this group. A very primitive testing base was set up at Kummersdorf.

Some time later Dr. Theiel, a specialist on propulsion, joined this group and soon became the chief assistant to von Braun. (Theiel and family were killed in the RAF raid on Peenemunde, 17 August 1943.) Von Braun is believed to have made a simple rocket called A-3, about five feet long and of small diameter, several of these being fired at Barkum, near Heligoland. At Kummersdorf they first tested a 700 kg unit and then later a 1000 kg unit. To study the burning relations of rocket chambers, a one cup injector (TOPF) motor was made of about 1400 kg thrusts. Then a rocket motor was made using three of the same type of injector cups. Here it was found that a long chamber was not necessary if a sufficiently high pressure was used. By 1936 Kummersdorf had grown too small, and the Heereswaffenant directed that they find a new testing station, this resulting in the choice of Peenemunde. The testing stations at Kummersdorf were retained for fuel and motor research. According to Rees, von Braun was too opitmistic and starter planning on A-4 back about 1935-36. Soon it was realized that a smaller model must first be built, primarily to develop the control system. Hence, the smaller A-5 had to be developed as a predecessor to the A-4.

As construction at Peenemunde proceeded in 1937, von Braun, Riedel I, and Riedel II eventually moved to this location, while Theiel stayed at Kummersdorf. Tests were well under way at the new location in 1938, during which time there was developed a little rocket called A-5. It was made of aluminum, its length being about five meters and diameter around 600 mms. All the early shots were conducted from Greifswalder Oie in the Baltic, a short distance from Peenemunde. The A-5 started vertically, then turned to an angle of about 45°. After the end of burning (Brennschluss), the rocket coasted on to a height of 19-20 km, and a horizontal range of 18-20 kms, at which point an open net type parachute was ejected which slowed the velocity from 120 to about 75 m/sec. A second chute of convential type fastened amidship was ejected which slowed the rocket down to 15 m/sec and lowered it gently into the sea. Thence it was easily retrieved by boat. All the steering mechanisms and recorders were inclosed in waterproof containers, flight records being obtained of the vains, roll, pitch, yaw, and other data as time histories. This rocket was also tracked by recording theodolites from three points.

In 1938 and 1939, 18 of the TOPF's were built into a single unit which developed a thrust of about 26 tons. Sanger, who developed rocket motors up to 40-50 and even 100 atmospheres, occasionally visited Peenemunde; he was not a member of their staff. To quote Mr. Rees, "Sanger was a scientist and not a practical man". Von Braun was thought to incorporate the good features of each. The chief development in steering began in 1939, when Dr. Steinhoff came to Peenemunde. (He was formerly a teacher in the Technische Hochschule at Frankenhausen, and then later with the Deutsches Versuchs Anstalt fur Lufthart.) He was an expert on electronics, radio, gyro-stabilization, and various test apparatus. In 1939 the army asked that the A-4 have a range of 275 kms with 100% (?) of the shots landing in a rectangle 1000 meters long and 500 meters wide. This was thought to be impossible without radio control. Rees thought this could be obtained perhaps in three to five years, but that it would necessitate manufacture of all parts with very small tolerances. The first drawings of A-4 were made in 1940, with the usual number of drawing changes which one might expect in such a development. Prior to late 1941, this group was called HVP (Heeres Versuchstelle Peenemunde, or sometimes Herres Versuchsanstalt Peenemunde). In 1941 its name was changed to HAP (Heeres Anstalt Peenemunde). On 6 July 1942 the A-4 was first fired as a missile. It rose about one meter from the ground, then exploded, destroying the testing station. The second was fired in August, this rising to approximately 5 kms before exploding. The performance of the third missile was about the same. The 3rd of October 1942 is described as a historical moment. The 4th A-4 flew satisfactorily, reaching the target area off Leba, about 270 km distant. The 5th impact was not spotted, but was believed to be all right. Difficulty was encountered with those from 6 to 19. Some of them broke in two, others exploded, and none reached the target. Beginning with 20 they had better success. Later in the development program the fire was from the vicinity of Leba, for land impact on the peninsula of Kurische, to the north of Konigsberg.

The middle series of A-4 production samples were built in the period of April through July 1943. It was originally planned to manufacture the A-4 (V-2) at Peenemunde. Director Rees would have been in charge. After the RAF raid, 17 August 1943 (which damaged mostly living quarters) it was decided impossible to establish production at this location, and Mittlewerk was founded by Mr. Degenkolb of the Speer Ministry. He was one of the chief men in the Speer Ministry of war production and had previously been quite successful in the manufacture of locomotives. Considerable friction existed between the Peenemunde group (Army) and Mittlewerk (Speer). Mr. Savatsky, formerly of Henschel, became works manager of Mittlewerk and began visiting Peenemunde regarding the production aspects of A-4. After this raid on Peenemunde, its name was changed to HAP-11, Heimat Artillerie Park 11, and spread out in little villages around the island of Usedom. By now Dorenburger had risen to be a General and was still the military officer in charge. Zanssen is also mentioned as being one of the head military men.

"Ostverlag" was formed in 1944, chiefly for the reproduction of drawings. It was first located at Kolpinsee on the island of Usedom. About November of that year it moved to Bad Sachsa in the southern Harz and later moved from there to Illfeld, about 2 kms north of the Mittlewerk factory at Nieder-Sachswerfen. On 1 August of this year, HAP-11 was incorporated as Elektromechanische Werke G.m.b.H. Of the early production at Mittlewerk, every single combustion chamber ("ofen") was tested at the "Prufstand", south of Saalfeld or near Oberraderoch. Every 10th A-4 produced at Mittlewerk in this early production was flight tested at Peenemunde. A-6 was reported to be practically the same missile as A-4 except that it was to use Salbei and a hydrocarbon. This development was not pushed, as the logistics of the liquid oxygen worked out satisfactorily. The A-7 was reported to be an experimental model for the A-9, similarly as the A-5 was for the A-4. This model was to be dropped from aircraft, one model actually having been tested. A-9 was an A-4 missile modified to take two wings amidship so as to increase its range by gliding. A small number of A-4's have been modified for this purpose, by having their center sections strengthened and swept back wings added to give a total spread of about 5½ meters. This was in an early stage of development with much aerodynamic model work remaining to be done. The A-10 was to be a two stage rocket, the first stage delivering 180 metric tons and the second about 26 metric tons, which is normal for the A-4. It was thought this rocket might reach a range of from 4 to 5 thousand kms within the next 5 to 10 years.

In this same year, 1944, the Speer Ministry decided there were too many rocket projects under development in Germany. It decided to concentrate on the final development and production of the following missiles: V-1, A-4, Taifum (both the 50 mm and the 100 mm flak rockets). Wasserfall, 8-117 (Schmetterling), R4M, the X-4, and possibly the X-7. It was reported that recent tests of the R4M by Rechlin based aircraft against Allied bombers, resulted in the downing of 3 bombers in 4 attacks. The X-4 was also believed to have been tested against the Allies. It is interesting that all of these weapons were either in final development or in early production stages.

By 1945 the total employment of the rocket development group at Peenemunde numbered about 4,500 persons. In February 1945 the army ordered the rocket research and development establishment, now known as Elektromechanische Werke, to evacuate to the vicinity of Bleicherode. Many of their laboratories and much of their equipment was to be located in the Kaliwerke mine, just outside of town. For this purpose 5,000 cubic meters of space was to be made available monthly for six months. It was reported that the Elektromechanische Werke expected to be fully back at work by the end of July. In the meantime, small workshops and storage rooms had been located in many of the neighboring villages and in other mines. The last boatload of equipment had left Peenemunde, and all people had evacuated mostly to the vicinity of Bleicherode when it was found necessary to evacuate important personnel to south Germany. It was thought by some that they would enjoy somewhat of a vacation until the Wehrmacht drove the Allies back across the German border, at which time the research people would return to their work.

(Not all of the information given in this brief historical summary is considered reliable. No attempt has been made to obtain a more complete summary, as it is believed that the interrogations of the large number of Peenemunde people recently interned at Garmisch will yield a more authentic record.)

Part IV. Details

1. Description of Wasserfall

This project was first proposed by members of the present development group in 1940. At that time there was no official interest shown in such a project. In 1943 development work was begun under government sanction in an enthusiastic manner at Peenemunde. By February 1945 design and construction was proceeding satisfactorily, 40 test flights having been made. On 20 February 1945 transportation of men and equipment from Peenemunde to the vicinity of Bleicherode began. Some of this equipment has arrived at its destination but no real work has been done since February.

Wasserfall (known also as C-2) is a ground to air, guided, winged missile propelled by a liquid fuel rocket motor. Its general outline is sketched in Fig. 1. Dimensions given are approximate as some are from Rees' memory.

Nitric acid (Salbei) and a hydrocarbon such as diesel oil or Visol are used as reactants in the propulsion unit. No booster units are used with the missile.

This missile is steered on a line of sight course toward its target by a joy stick device on the ground and radio link similar to that used with HS 293. As in most other guided missiles of this sort, the designers intended to incorporate a homing device and proximity fuse which w were not yet ready.

About 235 kg. of explosive material was placed in C-2 (W-5) but only 100-150 kg. in the war head proper. The rest was distributed around the missile body for self destruction.

In addition to the missile briefly described above as C-2 (W-5), a second Wasserfall about twice this size was also proposed in 1941. A third Wasserfall one-half this size, called C-2 (W-10), was calculated as being even better than the others.

Tactical Use: This projectile was designed for use against bomber formations or single aircraft flying at altitudes between 4 and 14 km. (13,000 and 45,000 ft.). Fig. 2 indicates approximately the volume that would be covered by this projectile. Although targets as low as 1 km. altitude could be reached it was not intended to use C-2 under 4 km. The 45 km.slant range appears optimistic unless the missile was to be used after its period of burning.

Another form of C-2 was to be developed for ground to ground shooting having a 120 km. range with a 90 kg. warhead.

Control and fusing was to be designed so that the 275 lb. blast effect charge plus the missiles from the disintegrating body would disable the target aircraft. The speed of this projectile is high, having an

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initial thrust of about 2.6 times its weight, increasing to 6.6 at the end of its 45 sec. run. In a vacuum this should give a terminal velocity of about 5,200 ft/sec. The actual final speed mentioned is 3,300 ft/sec. (Mach. no. = 3).

The designers believe that one bomber could be bagged for every two shots. At 7,000-10,000 marks per projectile the cost of destroying one bomber is say 20,000 marks. This compares favorably with standard flak which requires 4,000 shots at 100 marks each or 400,000 marks per bomber destroyed.

Performance: Sufficient wing area has been given this missile to enable it to make the turns necessary to follow aircraft maneuvers.

As indicated in Fig 1, Wasserfall is a long, slim missile equipped with 4 wings, tail fins, air rudders and graphite vanes in the exhaust blast. The general aerodynamic design has been carefully worked out in the supersonic wind tunnel at Peenemunde, usually at a Mach. no. of 3, although some details such as wing shape had not been finally settled. The nose is not a simple circular arc of constant radius but is a compound curve as dictated by wind tunnel measurements.

Four stub wings are placed near the c.g. of this body to assist in stabilization and control in relatively short turns. Since the missile is intended to follow the maneuvers of an allied fighter it is designed for turns of 4.4.g. At the tail four statilization fins are mounted. One large semi-balanced air rudder is placed on the rear of each fin. The rudder post projects inwards to carry a graphite vane operating in the jet blast. Since both types of control surface operate on the same shaft they turn through the same angles. Large air rudders were considered necessary for correcting roll at a larger moment arm than provided by the graphite vanes.

At present Wasserfall weights have not been exactly determined. The best approximation gives 3,000 kg. total, composed of 1,800 kg. of fuel and 1,200 kg. of body plus warhead. There are no droppable accessories.

Air Control: As mentioned above there are two types of control surfaces on the C-2, air rudders and jet vanes working in pairs on common shafts operated by push-pull rods from the four steering engines. Corrections for roll are made by the four shafts equally and simultaneously, while pitch and yaw corrections are superimposed on the appropriate shafts.

The graphite vanes, sketched in Fig. 3, are made by Siemens of sintered graphite. Ground graphite and a binder are pressed into a rough approximation of the final shape in one press at the Siemens plant in Plania. The plant is reported to have the only press in Germany suitable for this job. Pressing is followed by three sintering processes at a Siemens plant in the village of Meitingen near Augsburg. This process should be investigated more thoroughly both at Plania and Meitingen. The rough sintered blocks are then ground to shape with rounded corners as indicated in Fig. 3 on a copying machine developed at Peenemunde by Rees. This machine has a capacity of 40 finished vanes per hour.

These jet vanes, 10" long pivoted about 4" aft of the leading edge, which are essential for control in the initial stages of the rockets flight when air speed is low, constitute a resistance in the jet stream. Therefore they are blown off after 5 to 15 seconds of flight when they are no longer needed. This ditching is accomplished by a small explosive charge initiated by a timing mechanism, a radio command from the ground, or penetration of heat into the vane.

Electronic Control:

A. Source - The source of this information is Dipl. Ing. Helmut Grottrup, assistant to Dr. Steinhoff. The section under Steinhoff that was in charge of Wasserfall control was led by Dr. Netzer (section 224) who was somewhat secretive. Although the normal channel for information from the sections up to Steinhoff and von Braun was through Grottrup, Netzer frequently reported directly to von Braun. This was because Steinhoff was most interested in the A series missiles. As a consequence of this situation, Grottrup was able to supply only the broad outline of Wasserfall control.

B. Stability (Fig. 4) - Three separate gyros for the three axes were standard Siemens aircraft gyros with one pick-off each. These fed a Mischgerat which amplified the pick-off voltage supplied by the gyros and formed from it signals proportional to the gyro angle, its first and second derivatives, and its time integral. These were combined in optimum fashion to give the best possible range of stability for different velocities, changing mass and moments, air resistance coefficient, and control with and without carbon vanes. An additional device to improve the stability under the wide variety of conditions was a Zeitschaltwerk (ZSW) or time sequence switch which changed the amplification of the Mischgerat as a function of time in a manner that best matched normal flight requirements. For A-4, complete devices had been built to test not only stability about a point, but also path stability. However for Wasserfall only the test apparatus for stability about a point had been built. This device included pendulums and cams to simulate various physical conditions. The time integral of gyro voltage was required in the Mischgerat, said Grottrup, only for wind compensation and was given by the position of a motor whose speed was proportional to voltage.

The Mischgerat fed four separate servo control units (Antriebbs Reglar), one for each jet-and-air vane combination. These control units had appropriate relays for the particular type of servo that happened to be used.

The first type of servos to be used were individual hydraulic units with a motor and pump on each servo. These were either Askania LRM 15 or Siemens K 12/60. The next step was use of hydraulic servos with a common chamber of oil under gas pressure. These units were believed by Grottrup to be Siemens D19. Finally, just in the development state, were electric servos which were expected to be much better than hydraulic servos.

These electrical servos consisted of a vibrating polarized relay (about 50 cycles) and a d.c. motor which also vibrated sufficiently on its shaft to take up all back lash (Lose). The general plan as shown in Fig. 5 consists of a polarized relay whose contacts connect to two other relays. The contacts of these latter relays are connected back to the coils of the polarized relay to provide continuous oscillation with equal dwell on the two contacts. A signal from the Mischgerat applied to the polarized relay causes the dwell on the two contacts to become unequal. This causes a net motor field component which rotates the servo motor.

It is claimed that in hydraulic systems without oscillation the back lash may be as much as 1/3 the travel causing a characteristic as shown in Fig. 6A, compared to the electric servo characteristic of Fig. 6B.

Finally, in Fig. 4, there are feed back potentiometers from each steering motor back to the Mischgerat.

All four rudders are used for roll control. These four rudders are separate, and not mechanically interconnected.

In the laboratory a system using three rate gyros was tried and thought better because there was no trouble with gyros reaching their stops. The Mischgerat had to be altered to start with the rate signal, and form both second derivative, position signal and time integral of position signal.

C. Control - To put the Wasserfall through the target point in space:

The system used on the few controlled flights made was simple. Just as in the control of the HS 293 a joy stick (Knuppel) feeds signals from two potentiometers into a Strasburg transmitter. A Kehl receiver in the missile picks up these signals and delivers them to the stability control system at either of two places or at both. The optimum proportions had not yet been settled.

One of the places is at the gyro pick-off. A motor turns the picl-off card in response to the received signal. The second place is into the Mischgerat output to the servo controls. The purpose of the latter is fast actions while the former in some proportion may be required for stability.

The proposed method of operation was to have the Wasserfall take off vertically, and be guided by manual control of the Knuppel until the missile optically coincided with the target. The motion of the Knuppel must be restricted during this period to avoid exceeding the maximum c control acceleration for which the missile is stable. Grottrup did not have any figures on these accelerations. Once target and missile are optically coincided the system is what we know as a beam-climbing or line-of-sight system.

It was proposed to replace the man at the Knuppel with a computer device on the ground which attached to the optical instrument for tracking and supplied some degree of prediction to improve the path.

Apparently only 6-10 flights had been made with control, and these were program shots with a predetermined flight plan and no target so no information as to the effectiveness of the device could be obtained.

Other methods of control were being contemplated, such as homing devices. Proximity fuses were being planned. Dr. Slevogt of Dr. Netzer's section worked on these devices and further information should be obtained from him by interrogation at Garmische.

Propulsion: The general arrangement of the propulsion system including tanks and principal piping is shown in Fig. 7. A pressurized tank system is used in this rocket although the size is more suitable for a pump system of reactant supply. This simplification was made to reduce manufacturing costs and increase ease of handling since this weapon was to be produced in large quantities. At the rear end of the projectile's nose section is placed a spherical air flask (not wire wound) 8-13 mm. thick which contains dry air at about 200-300 atmospheres pressure 2,950-4,400 lb/in^2.). A bent tube running through this air flask is used to conduct electical leads from the fusing mechanism in the nose to that part of the explosive which is distributed throughout the body of the missile. Immediately aft of the air flask is the main reactant tank assembly which does double duty as an airframe. The hydrocarbon tank forward is securely joined to the larger acid tank aft by a cylindrical ring welded to both tanks. All tank construction is rolled and welded steel. Both main tanks are provided with an axial cavity to accommodate piping. The high pressure air lead is brought aft from the air flask, through a hand valve to a reducing valve between the main reactant tanks which supplies 25 atmosphere (370 lb/in^2.) air directly to both reactant tanks.

An ingenious device is used to conduct the reactants out of their tanks in a continuous stream in spite of radial accelerations as the missile follows its target. From a rigid pipe near the top of each reactant tank is suspended a section of flexible tubing whose open bottom end just clears the rounded tank bottom. This flexible tube is a metal bellows of the Sylphon type. As the missile is given radial accelerations the liquids rush to one side of the tanks but are followed by the flexible tube insuring that the tank outlet will be covered at all times. It is reported that this device raises the maximum altitude reached by C-2 in test from 12 to 16 km. The flexible tube scheme appears superior especially in weight and ease of manufacture to Wagner's system using an air driven piston.

Air pressure forces the reactants from both tanks aft to a pair of valves in the main lines opened simultaneously by a single powder operated piston shown in drawing SKW 3903.1039. Other means were being considered for opening this pair of valves such as air pressure and electrical. The main valves are backed up by a pair of diaphragms, one in each reactant line which burst at less than 25 atmospheres pressure. These diaphragms perform two functions; prevent valve leakage reaching the combustion chamber, and insure that there will be no slow build up period to the reactant flow. The designers believe that they will obtain the best results with an instantaneous change in flow rate from zero to full.

From the diaphragms the hydrocarbon is led directly to the nozzle head while the acid is piped in a single line to the venturi exit where it enters a cooling jacket through which it passes before entering the nozzle head. There are several rows of auxiliary cooling holes leading acid directly into the combustion chamber in the flame front area and just upstream of the nozzle throat.

The reactants used in C-2 are Salbei and Visol in the proportions 5:1 to 8:1. The ratios vary with the exact constituents of the oxidizer and fuel used but are generally calculated for stoichiometric proportions.

The designers would have liked to have used 97% HNO_3 (3% H_2O) in a special chrome steel tank (German steel no. 1604) but as this steel was unavailable due to chromium shortage they added 10% H_2SO_4 to the nitric acid and used a commonly available steel, no. 1265, to get about the same corrosion characteristics as in the previous combination. As these missiles were fueled some time before launching corrosion problems were necessarily considered. A higher concentration of HNO_3 than 97% is not necessary since about 3% of water would be taken up from the air on handling in any case. The HNO_3 used is the standard acid, not red fuming nitric.

Visol is a synthetic fuel representing a joint development of most of the German chemical industry integrated by Dr. Heller of EMW. Proportions of ingredients varied from time to time with paticular requirements and supply possibilities. A typical composition is 40% isopropyl alcohol, 40% vinyl ether, 2-3% water and 18% of four other ingredients including dopes. Spontaneous ignition of these reactants was desired within 0.1 to 0.01 sec. after contact. A photo cell ignition time measuring device was developed for measuring the ignition delay of various reactant combinations at atmospheric pressure. Ethyl fluid, probably tetra ethyl lead, could be used to reduce ignition time. Another dope which was thought to be a ferrocarbonyl (Eisen penta carbonyl) could be used in small quantities to speed up ignition, in larger quantities with no effect, and in greater proportions to slow down ignition time. Other ingredients of Visol were not recalled by Riedel III.

The combustion chamber and venturi as used on Wasserfall are sketched in Fig. 8 with dimensions as remembered by Rees. It appears to be a conventional jacketed combustion chamber with a deLaval type nozzle having a reported expansion ratio of 2.5 to 1. up to 3.9 in one model which was measured. The inner and outer walls are spaced by lengthwise members following the elements of the geometric figure. About 2% of the Salbei is admitted directly to the combustion chamber through 3 rows of holes, one at the max. dia. of the chamber and another just upstream of the throat and a third row of very few holes between (see Fig. 8).

The problem of differential expansion in combustion chamber jackets has been studied for two years by Thiel. Wasserfall jackets have had expansion joints at various times but in the final design the Salbei distributing ring at the bottom was supposed to supply all of the relative motion necessary.

A special steel with Ni, Mn and Cr was considered the best combustion chamber material but it was necessary for supply reasons to use a 1.3-2% Mn, 0.4% Si, .25% C steel although this was unsuitable from the performance and forming viewpoint.

Gas exit velocity in the production models was to be 1,850 meters/sec. (6,090 ft/sec.) although 1900 meters/sec. was reached with various forms of test injection nozzles. 6,090 ft/sec. jet velocity indicates a specific impulse of 189 sec. which compares reasonably well with a S. I. of 178 sec. calculated from an 8,000 kg. thrust for 40 sec. at a fuel expenditure of 1,800 kg. A higher SI could be obtained from a liquid O_2 - fuel combination but the using services did not consider liquid O_2 acceptable as this weapon was supposed to be ready at any time for flak use. Even in the planned firing of V-2, 35% of the liquid O_2 made is lost in storing, handling and transit. For use with a projectile requiring long standby times this and other problems such as icing would be more serious. In addition Visol has a higher specific gravity than alcohol allowing smaller tank space, an important point in a pressurized system.

The combustion chamber head or nozzle block has been the subject of considerable experimentation. Apparently one of the latest arrangements was as shown in Fig. 8. A solid steel disk drilled radially as shown distributed the Salbei in the disk and out into the combustion chamber through smaller axial holes 0.08 to 0.10" dia. Visol was admitted to the combustion chamber by many .03 to .05 holes drilled axially through the nozzle disk. Hole numbers and sizes were chosen to admit the reactants in the proper proportions. Pressure drops are given as high as 10 atmos. for some arrangements down to 1.5 atmos. for the production model.

The parallel jets emerge from the nozzle plate about as shown in Fig. 9. Heat and turbulence cause complete vaporization within about 3 in. These envelopes mix and spontaneously ignite giving a quite definite flame front.

Several other forms of reactant injection have been tried on the Wasserfall combustion chamber. Fig. 10 shows a cross-section of one in the form of a circular slit divided by a central partition (ringspalduse). Two thin sheets of reactants emerge to impinge at A where ignition begins. Considerable difficulty was experienced with supersonic vibration due to the instability of point A. A partial vacuum in space B encouraged vapor formation in that space which influenced the point of spontaneous ignition. This effect set up a form of self induced vibration at high frequency which was reported to damage the combustion chamber.

A type of conical spray nozzle formed by a conical hole into which a reactant is admitted tangentially has been tried. A number of these nozzles spaced with block at the head of the combustion chamber produce conical sprays of reactants. This device is not considered practical since the region in which stoichiometric proportions exist is small.

Still another arrangement of holes in the nozzle block is similar to that shown in Fig. 8 except that the holes are so inclined that the two reactants impinge in pairs at many points. This scheme works well but is difficult to manufacture. In fact work was going on to develop an inclined hole which could be punched. It was expected that the parallel jet holes in the final design would be punched in production.

As mentioned above only 125 kg of Wasserfall's explosive charge was placed in the warhead proper, the remainder being distributed in tubes around the structure in a form similar to primercord. Since C-2 was to be used as flak over home territory it was desirable that the projectile be completely self destructing. It is for this reason that the through tubes are in the centers of the fuel tanks rather than at the outside in spite of the fact that the central location interferes with the action of the flexible reactant feed pipes.

Fusing devices had not been perfected. It was intended to use one of the forms of proximity fuse in development as well as a time actuated self destructing fuse.

38204-2

Wasserfall is launched vertically in a manner similar to A-4 but without the positioning refinements necessary in the latter launching proceedure. Due to the four stub wings on C-2 it is in danger of being tipped over by a high wind. Explosive bolts have been used to hold the missile in place until the moment of firing when the bolts are blown. Riedel III states that 20 such bolts can be fired with a time difference of only .001 sec.

The missile leaves the launching platform under the full 8,000 kg. thrust of the rocket giving an acceleration of about 1.6 g. based on the weight figures given previously. After the projectile has stabilized itself in flight it is steered toward the target by means of the joy stick control. Final acceleration would be about 5.6 g. in vacuo.

Project Status: At the time of the Peenemunde evacuation in February 1945 work on this missile was rapidly proceeding to the production stage. Some details remained to be perfected on the missile itself but the general design was complete. Proximity fusing was as far behind as any of the details.

Program firing tests had been made on the completed projectile. In this test the projectile is launched in the usual manner and then controlled from the ground in a series of predetermined manoeuvers following a precise time schedule. The trajectory of the missile is followed by three recording theodolites. Later the program and the recorded trajectory are compared. Results of such tests were said to be satisfactory. Burning time had reached the 38-40 sec mark although 45 seconds was desired.

Every effort was being made to bring this development to the production stage as soon as possible.

ADDITIONAL NOTES ON WASSERFALL

On 25 May 1945, Riedel III brought in some data reported below which he had been working on.

The total weight of reactants loaded into the C-2 tanks is 1,985 kg. in the proportion 0.3 to 1.0 of Visol to Salbei. About 25 kg. of reactants are burned before the rocket lea ves the ground so that the remaining liquid in the tanks is Visol - 452 kg. and Salbei - 1,508 kg.

The total weight of the entire rocket on leaving the ground is 3,600 kg. made up as follows:

Total weight at instant of take off	3,600 kg.
Salbei	1,508 "
Visol	452 "
Dry rocket without air or explosive	1,370 "
Wt of air in pressure bottle at 300 atu	80 "
Explosive	190 "
Total	3,600 kg.

The fuel rate in C-2 is 5.13 gm/kg.sec. which indicates an SI of 195 sec.

If the air flask is made of 12 mm. thick 2.5% Mn steel with an elastic limit of 50 kg/mm^2. it will just hold air at 350 atu. 300 atu is considered safe.

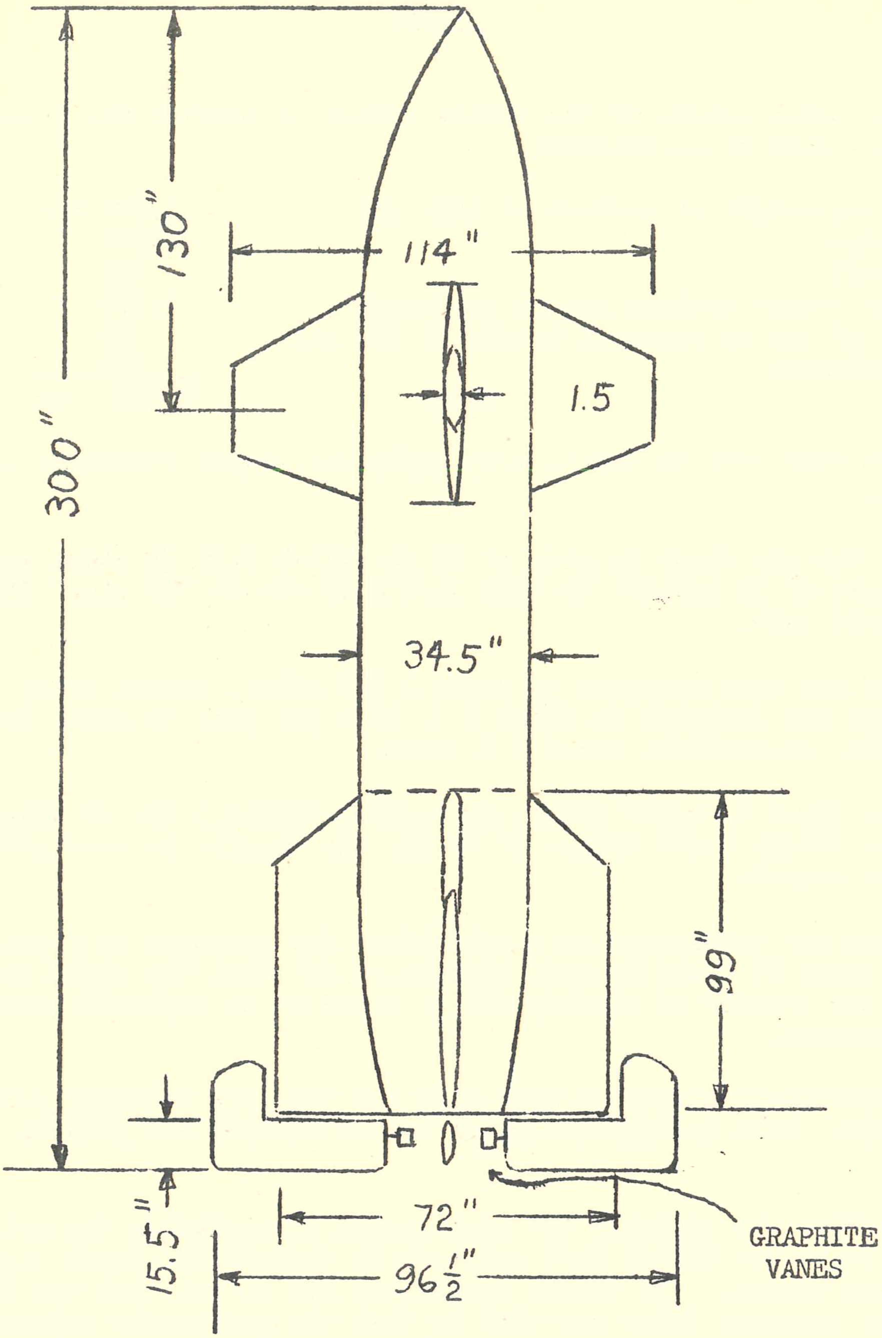
C-2 has been designed to catch a 250 m/sec. target doing 2 g. turns. The wings are designed to stand 8 T. lift per pair to which the body, tial, etc. contributes about 4 T. more.

The speed of 1,000 m/sec. is reached within 5 km. of flight. In order to attain slant ranges of 45 km. the missile is used after propulsion has ceased.

Wood was considered as a substitute for graphite as a jet vane material since it could be made to burn up in about the right time thereby saving the trouble of blowing off by means of an explosive charge as had been intended.

Experiments have been made with the tail fin assembly set at 45° to the wings. This arrangement gives better control but greater air resistance.

Another and probably the best method of operating the main fuel valves is to use Salbei tank pressure to operate the power piston which opens the valves. The valves themselves are so set that the Salbei which is admitted first has time to fill the combustion chamber cooling jacket and arrive at the nozzles coincidentally with the Visol.



WASSERFALL

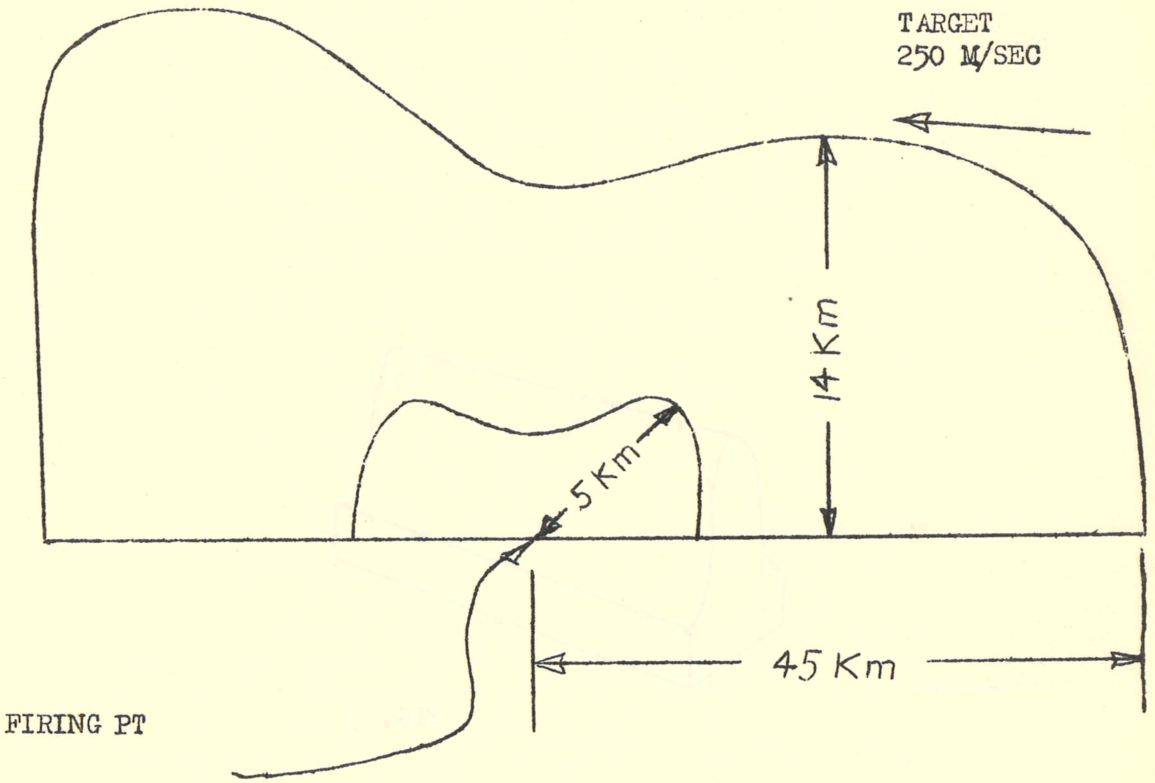


FIG. 2

38204-2

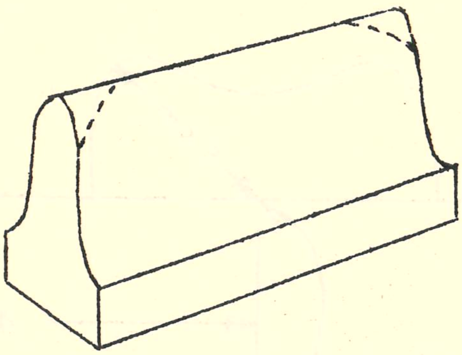
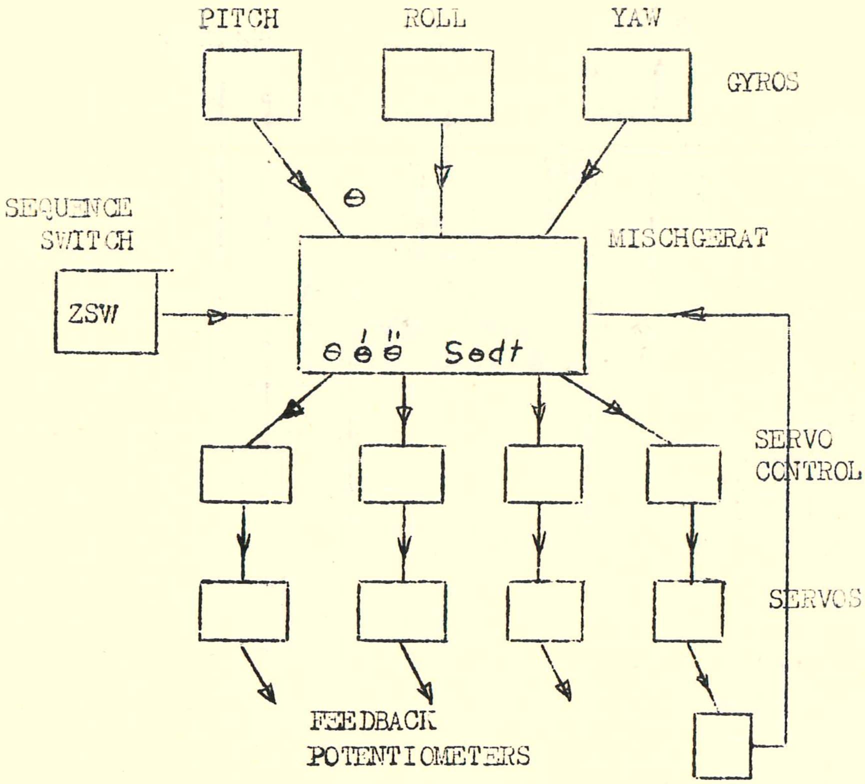


FIG. 3



PITCH
ROLL
YAW
GYROS
SEQUENCE SWITCH
ZSW
MISCHGERAT
SERVO CONTROL
SERVOS
FEEDBACK POTENTIOMETERS

FIG. 4

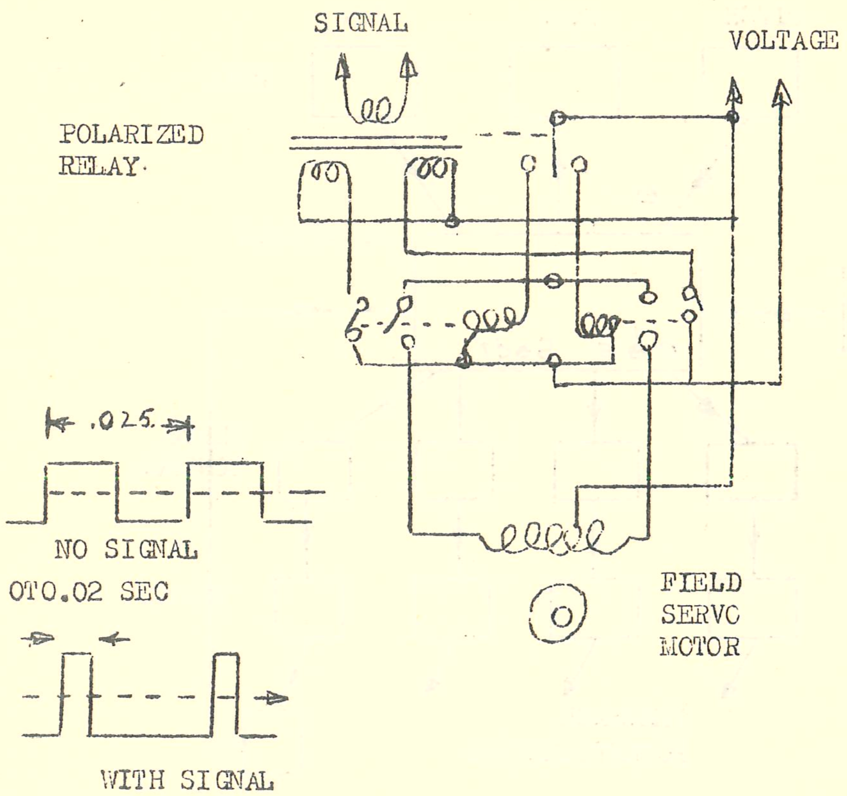


FIG. 5

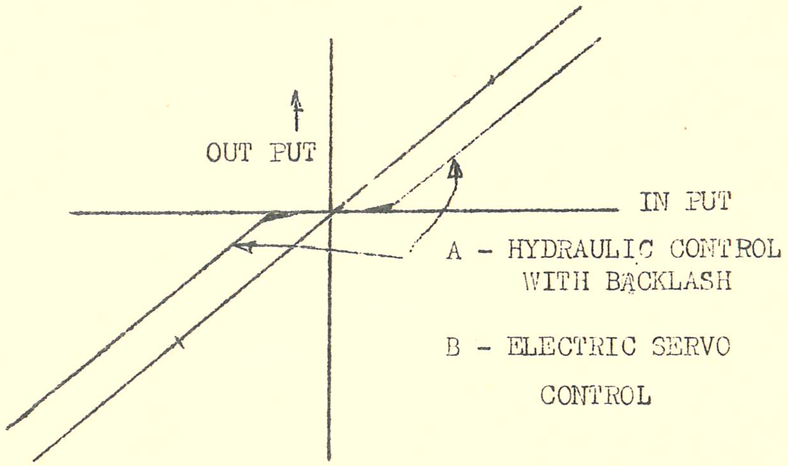


FIG 6

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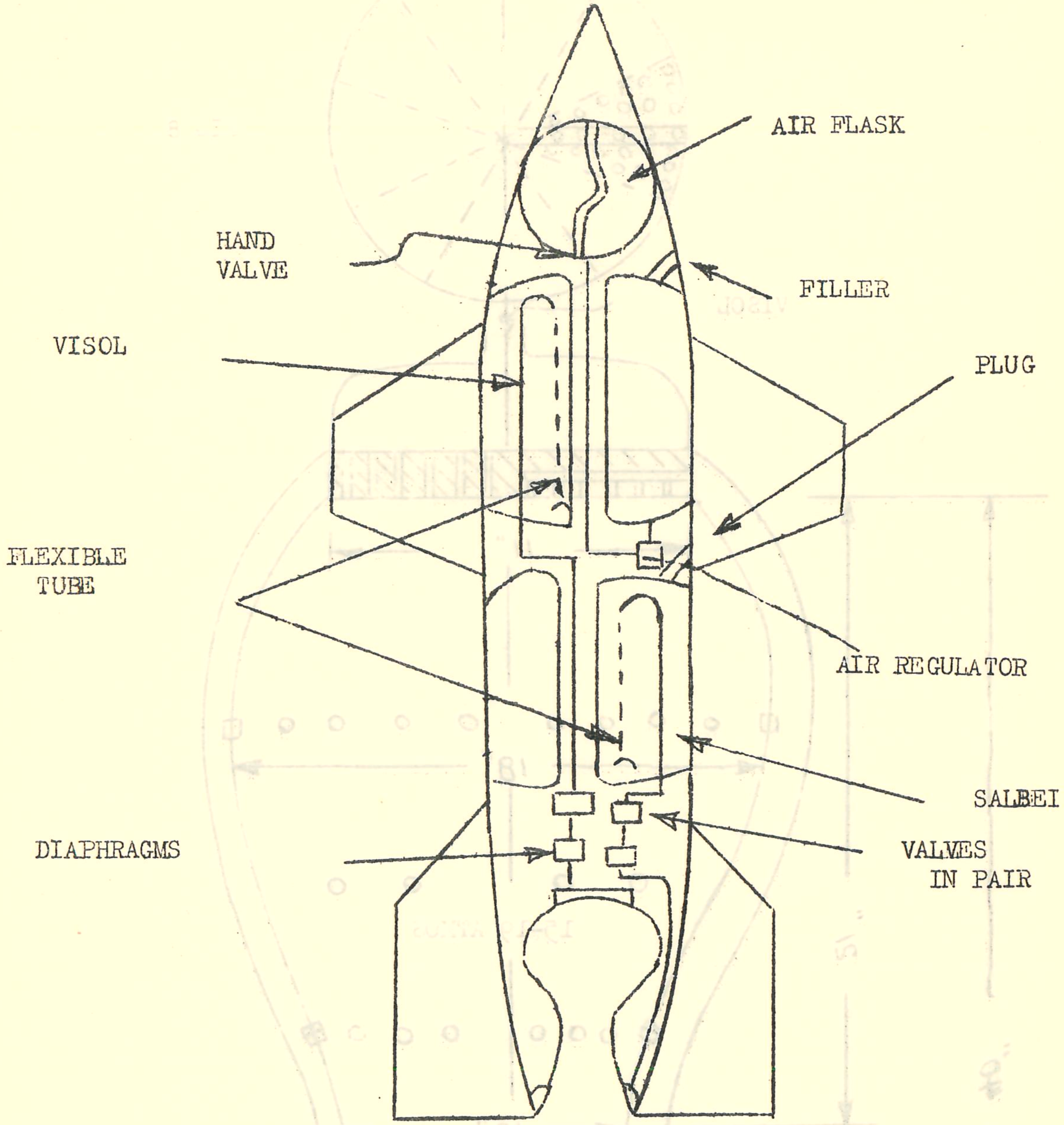


PIPING

FIG. 7

3820A-2

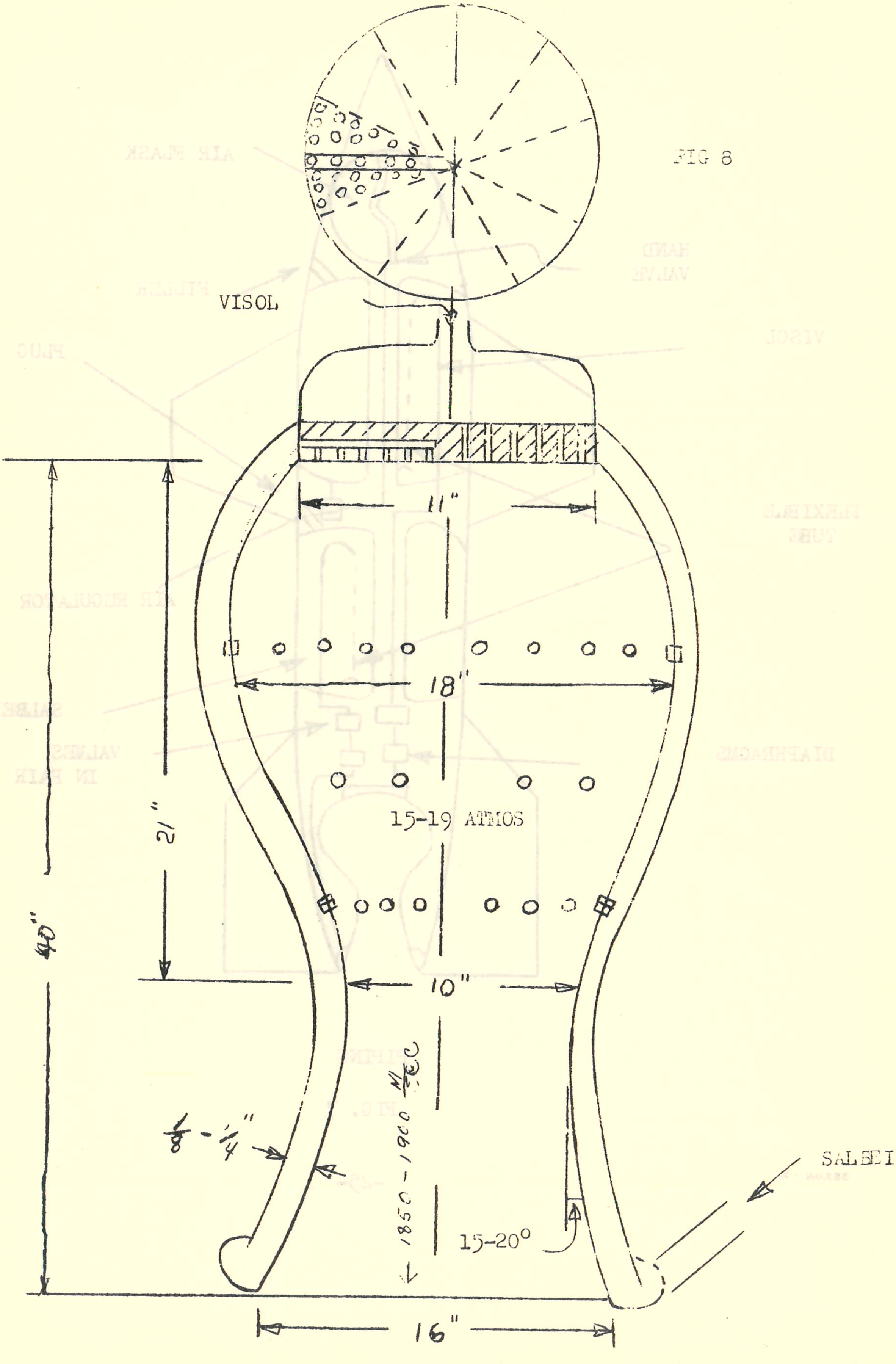

VISOL
11"
18"
15-19 ATMOS
21"
40"
10"
1850-1900 M/SEC
1/8 - 1/4"
15-20°
SALEEI
16"

FIG 8

38206-2

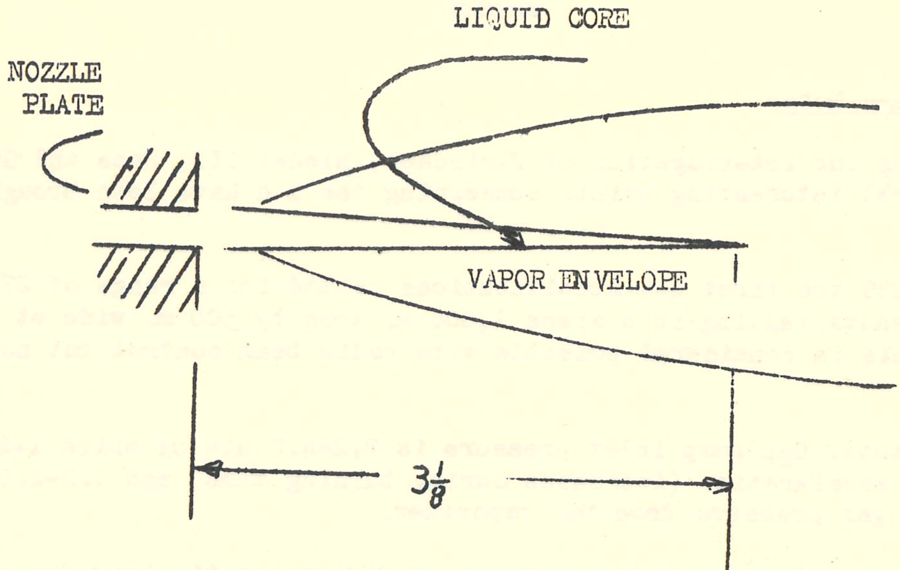


FIG. 9

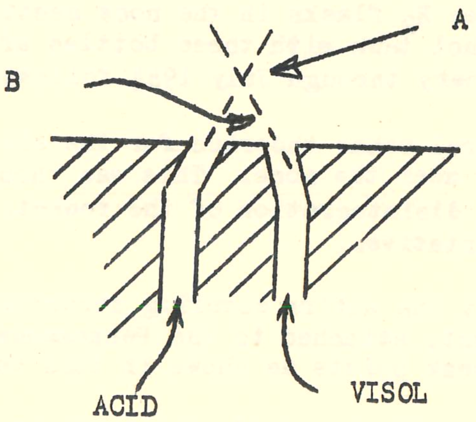


FIG. 10

58204-2

2. A-4 Notes

During our interrogation of Fleischer, Riedel III, Rees and Grottrup several interesting points concerning the A-4 have been brought out.

In 1939 the first A-4 specifications called for a range of 275 km. with all shots falling in a space 1,000 m. long by 500 m. wide at that range. This is considered possible with radio beam control but not without.

The total O_2L pump inlet pressure is 2.2-4.0 atu of which 1-2 atu is due to acceleration (increases during burning time) and 1.2-2.0 is due to O_2 gas pressure from the vaporizer.

The alcohol pressure is composed of 0.3 atu static head due to the position of the tank, 1-2 atu due to acceleration and an additional varible pressure due to the dynamic head of air admitted from the nose. Note that atu indicates pressure in atmospheres above normal atmospheric pressure while ata is the pressure above absolute zero.

At one time the Germans thought that air explosions of A-4 were due to an implosion of the alcohol tank on reentering the atmosphere. Therefore they placed three N_2 flasks in the nose section of the rocket and pressurized the alcohol tank with these bottles after the first 40 sec. Shots made from February through July 1944 followed this procedure.

There were several other theories for the air explosions of A-4 such as skin flutter near the nose. This was thought to cause tearing open of the skin and disintegration of the rocket. A double nose skin was added as a preventative.

In order to test the entire covering structure for weak spots and A-4 was made air tight, attached to the Peenemunde wind tunnel sphere and evacuated. The weak points as shown in this test were strengthened.

During this time 100 test A-4's were made at Mittlewerke and fired in Poland. After trying various devices the percentage breakups was reduced from 60% to 15 or 20%. The designers felt that they had solved the problem on the way up but not on the way down.

As is known in starting the burner, O_2L is admitted first followed by alcohol. In order to prevent O_2L from being forced up the alcohol holes in the topfs a cylindrical paper barrier is placed in each topf.

The initial thrust of A-4 is 8T which is not sufficient to raise the rocket. Full 25T thrust is then applied until the pre Brenschluss signal when the thrust is cut to 8T (all metric tons) which produces about 1 g acceleration to allow time for a more accurate determination of velocity. The duration of the 8T thrust is about 3 sec.

Each of the H_2O_2 generators, turbine pump units and venturis composing the propulsion system of an A-4 are tested separately and then matched in assembly in order to produce a standard thrust.

The H_2O_2 units produce saturated vapor at about 275°C. and at a rate which is measured in test. About 15-18 kg. of potassium permanganate and 120 kg of H_2O_2 are burned in 60 sec.

Turbine tests are made at load under constant conditions. Water supplied from a 3 meter head is used in place of O_2L and alcohol in this test. Output pressures are the same as in A-4, that is 27 atu for the alcohol and 25 atu for the O_2L pump. Turbine speed for these conditions is measured. Normal units fall between 3,800 and 4,000 RPM.

The venturi units are statically tested in the prufstand south of Saalfeld. During this test two reactant rates and four pressures are measured; the four pressures being O_2L at the inlet to the topfs, alcohol pressure at the entrance to the jacket, and at the exit from the jacket, and the combustion chamber pressure.

Test data from each unit is studied at the assembly plant where three suitable units are matched to form one standard propulsion system. For instance a combustion chamber requiring a high reactant pressure drop is matched with a high speed turnbine and a high capacity H_2O_2 unit. In this way the standard jet velocity of 2,050 m/sec. is maintained.

The eccentric gadget on the outboard end of the alcohol pump shaft is an overspeed device which permanently shuts down the steam plant if the turbine speed reaches 5,000 RPM. This will operate if either reactant fails to feed, thus preventing a turbine explosion.

The A-4 has been manufactured and used with two different sizes of aluminum tanks. Also three different insulation schemes are used. By using a minimum of insulation and large tanks the burning time can be increased from 63 to 68 sec. and sometimes as high as 70 sec. giving a maximum range of 390 km.

Steel tanks have also been manufactured.

Riedel III has developed a treated textile, flexible, alcohol tank which has severaladvantages, usch as saving transport room, conserving aluminum, saving weight as it weighs only 80 kg. for a tank holding 1250 kg. of alcohol, and its collapse under external pressure does not cause trouble. A-4's equipped with these tanks have been shot to England.

There has also been developed a paper O_2L tank made from compressed wood paper with a small amount of rag stock added. The tank is treated on the outside but not inside. Its total weight is 120 kg. for a wall thickness of 5mm. No insulation is required on this tank thereby saving additional space and weight. In addition the tank is more rugged for transportation and handling. No rockets containing this type of tank have been shot to England.

In normal firing it is desired to leave at least 125 kg. of reactant in each tank after Brennschluss. However the A-4 system is equipped with an Ausbrenner command which will allow burning until one of the reactant tanks is empty.

In the later A-4 shots 75% alcohol was used. In order to prevent corrosion 1 to 1.5 parts per thousand of potassium bichromate (Kalium bi chromat) were added.

Graphite vanes for the A-4 are made with a bulge projecting radially inward from the leading edge. The reason given for this design is that as the vane burns away approximate balance should be preserved. As the bulge is placed at the point of greatest erosion it may help to preserve the final shape but probably not the balance.

The amount of alcohol added directly to the combustion chamber and venturi for cooling is stated by Riedel III to be not over 10%.

In vertical test firings A-4's have been followed visually 150 km. up by means of special theodolites. For such a test the rocket is painted yellow and fired after sunset, but while the sun is still shining at high altitudes.

The last production A-4's did not contain a gyro type of integrating accelerometer.

Production costs of A-4's are given as 50,000 marks at the beginning, 25-30,000 at the production peak of 600/mo. and should have reached 20,000 marks at the intended production of 900/mo.

In the neighborhood of Lauenstein, 80 km. south of Weimer, is situated the test stands for A-4 motors as well as a large O_2L plant. This development is built into an extensive slate quarry on a hill top, off the main road. The O_2L plant is entirely underground in tunnels entering the face of the quarry about half way down. Twelve units produce 120 T/day of O_2L with 6 more units being set up or projected. There is storage for 150 m3 of O_2L.

Mounted on the side of the cliff are two static test stands for A-4 venturis, in which the unit to be tested is run out on a platform over the edge of the quarry side where it is allowed to exhaust through a hole in the platform. Thrust is taken by jacking the venturi down from an overhead structure. Six measurements are taken as mentioned above in describing the production tests of these units. During test runs the noise has been heard 100 km. away.

This plant has not been damaged in any way. The operating personnel who are present state that they could set up to manufacture O_2L and test venturis within one week.

Additional A-4 Notes

On 24 May 1945 Specht was interrogated at Ilfeld by Lt. Harker, Navy Tech. MISU and the writer bringing forth these additional facts concerning A-4. In some respects these notes do not agree with those written previously (21 May).

Two types of A-4 ignition have been employed. The first, which was never satisfactory, developed in this way. Originally a single tube led a phosphorus compound into the venturi chamber where it was sprayed out. On coming in contact with air the phosphorus spontaneously ignites When the venturi temperature has reached a required level alcohol is admitted and 1/10 sec. later O_2L. Combustion chamber temperature is measured by means of a thermocouple on the vertical support for the phosphorus tube. Occasionally this device did not ignite so in order to start fresh the venturi was purged with nitrogen brought from a flask in a second tube. Then to insure having ignition conditions again, air or gaseous oxygen was led into the venturi through a third tube.

This unsatisfactory system was replaced by a pyrotechnic firing device consisting of two 10 sec. Roman candles placed on the ends of an horizontal wooden cross arm pivoted at its center on a vertical wooden stick running up into the combustion chamber. On electrically firing these candles burned, rotating the cross arm pinwheel fashion. Chamber temperature was taken as before. This device is reported to be satisfactory.

As mentioned above when ignition temperature is considered satisfactory alcohol is admitted through all normal alcohol jets, then O_2L. The turbine is not running at this time allowing only the static head of the liquid in the tanks to supply reactants to the jets. When the resulting flame is considered satisfactory from visual observation the turbine is brought up to speed in 1 to 2 sec. and the missile takes off. Under the static head of the reactants an 8 T. thrust is developed, with the pump running this is increased to about 30 T. The missile does not rise under the 8 T. thrust. On the average the 8 T. thrust is run for 1-2 sec. only before starting the turbine.

Specht reports the turbine speed as 3,000 RPM and the eccentric cut out at 3,400.

Flame temperature in the combustion chamber runs from cherry red to yellow at a pressure of 14 atu.

The potientiometers in the reactant valves are stated to be used for observation in the control point only.

Nozzles in all topfs are adjusted to meet at a single point in the combustion chamber.

In cold weather the combustion pot is prewarmed before firing to reduce mechanical failure due to heat shock.

<u>A-4 Notes from Riedel III on 25 May 1945</u>

Fig. 1 shows a thrust time graph of the A-4 propulsion unit. After ignition the rocket is allowed to burn under the static head of the reactants for about 2 sec. Then if visual observation indicates a steady flame the turbine is brought up to its full speed of 3,850 RPM which requires 0.6 sec. The rocket takes off 0.8 sec. after the turbine is first started. As atmospheric pressure is reduced with the altitude of the rocket, the thrust reaches 29 T. after 60 sec. of flight.

The weight of reactants in the rocket at the instant of leaving the ground on a 250 km. flight is:

O_2L	4,817 kg.
Alcohol	3,855 "
Total reactants	8,772 kg.

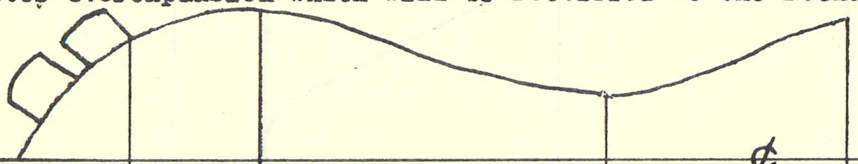
Reactant flow rates are:

O_2L	69.2 kg/sec
Alcohol	56.0 "
Total	125.2 kg/sec

Ratio of alcohol to O_2L is 0.81 by weight.

A specific impulse of 200 sec. is indicated by the figure of 5 gm/kg. sec. for reactant rate per unit of impulse.

Fig. 2 indicates the sea level conditions for velocity, temperature and pressure inside the burner. The exit pressure at sea level indicates overexpansion which will be rectified as the rocket gains altitude.



				℄
Vel		112	1018	2050 m/sec.
Press	15.2	14.2	7.6	-0.16 Kg/cm^{2}gage
Temp	2660	2660	2420	1615 °C
Dia		948	400	740 mm.

A-4 Offen

Fig. 2.

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THRUST METRIC TONS

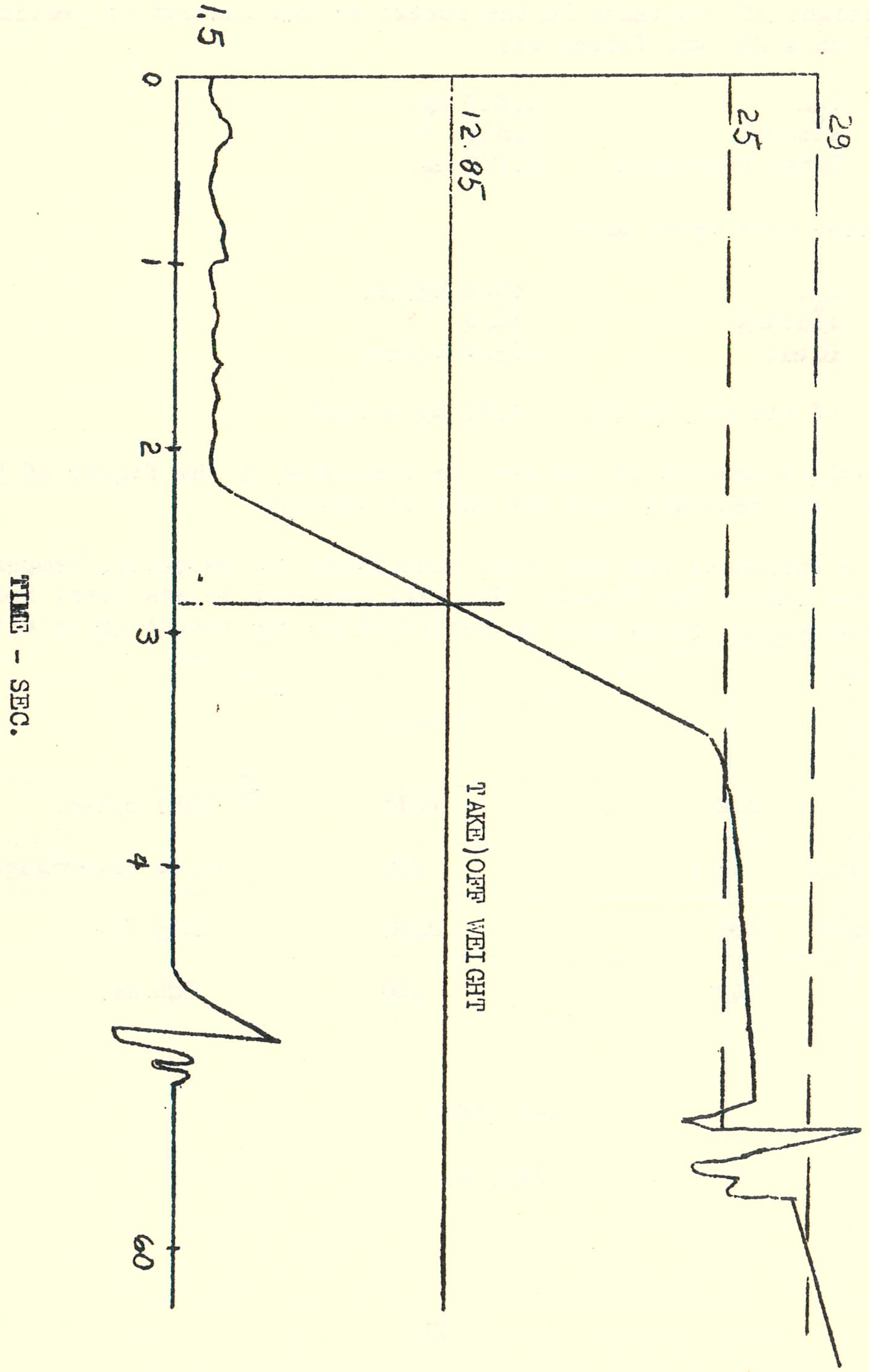


FIG 1.

3. Notes on Various Rockets

Ensian: This is a ground to air missile propelled at subsonic speeds and controlled by normal ailerons. Its general outline and approximate dimensions are about as shown in Fig 1. The warhead carries a charge of approximately 105 kg.

Messerschmidt built the first bodies of wood but production bodies were to be of pressed paper about 25 mm. thick with a few wood frames installed for mounting apparatus. Wet paper pulp was to be placed on porous mould, the mould evacuated and then both the mould and paper heated at about 100°C. to cure.

An H_2O_2 propulsion system by Walther of Kiel is used for main propulsion. In addition there are four boosters placed as shown in Fig. 2. These boosters are released by powder pistons at the end of their useful life. Small tilted stub wings (see Fig. 3) on each booster help carry it radially outward away from the missile after release. Rhein Metall Borsig and Wasag make the boosters.

Control is reported to be of the same type as HS 293, but simpler.

Rheintochter: Has been designed by RMB in three types, all being intended for ground to air use. Type I (shown in Fig. 4) is a two stage 4 winged, solid powder rocket. After the booster on the rear is burned out it drops off. The missile is then propelled by the main charge exhausting through about twelve nozzles as shown at the left of Fig. 4.

Type II is the same except that in place of the rear booster it carries four droppable booster rockets, set between the wings.

Type III derives its boost in the same manner as II but is propelled by a liquid fuel unit. In this pressurized system the air sphere is fastened directly to the combustion chamber end of the venturi unit. Reactant tanks are forward. All piping leads outside of the tanks. Liquid is takne from the tanks by the same flexible pipe scheme as used in Wasserfall. Control is attempted by two nose vanes.

These missiles are supposed to operate in the supersonic range although the development probably isn't far enough along to determine characteristics at these speeds.

Taifun: Is reported to be made in two sizes with both liquid and solid propulsion systems for both. In the small size the powder version is more nearly perfected.

Fohn: Indicates a small ground to air rocket for use against low flying aircraft. Its size, 3 cm. in diameter by 60 cm. long, is about the same as that of the small Taifun.

X-4: Indicates a wire controlled air to air missile having in Riedel III's opinion a maximum range of 5 km. and a present flight distance of 2 km.

In this connection Riedel III mentioned that wire control had been considered for A-4 during the burning period.

Rotkappchen (little red cap): Is a flying double Panzerfaust intended for ground to tank use. Development on this missile is reported to be nearly complete. Fig. 5 shows a general outline of the projectile. It is reported to be set off from two Panzerfaust launchers and wire controlled to its target by means of a circuit provided by the wire from the spools mounted on each wing tip.

Rochen: Is similar to the previous missile but carries only one Panzerfaust (Fig. 6). It is launched in such a direction that it pancakes upward and forward and then glides toward its target. Wire control is used on this missile which is stated to be effective up to 3000 meters. Experimental flights at Hela indicated many aerodynamic difficulties.

Flunder: Indicates a missile which was intended to combine the good points of the Rotkappchen and Rochen into an effective anti tank weapon. BMW had started this work but never brought the project to test.

4. Miscellaneous

Riedel III has reported that a new rocket fuel has been developed in Germany, tetra nitro methane. This oxygen carrier was to be used with Visol to give a calculated specific impulse 20% greater than that obtained from liquid oxygen and alcohol. No rocket tests have been made with this reactant as yet. The cost of this fuel on a laboratory basis is 10 marks/kg. but calculated production figures for large quantities indicate 0.40 marks/kg. or the same cost as gasoline in Germany.

At the end of March 1945 when Riedel III left Peenemunde there were 10 metric tons stored there. As there was no destruction intended at Peenemunde this chemical may still be available.

In developing Wasserfall aerodynamically weighted models were dropped from airplanes at altitudes of 12,000 meters in order to study the stability of the design. One such model of Wasserfall was 77" long by 8.8" in diam. or scaled down about 3.6 to 1 from the full sized projectile.

This device is reported to be very effective in the study of body stability over a wide speed range.

At Peenemunde there was built in 1938 a supersonic wind tunnel which was reported to be intact when the EW group left. In this apparatus a 1,000 cubic meter sphere which is 99.8% evacuated is allowed to fill rapidly with air through a duct containing a throat and expanding nozzle. The nozzle exit where models are placed is about 40 cm. square allowing models 30 cm. long by 5 cm. in diameter and 10 to 12 cm. over the wings to be studied. In this tunnel a Mach. no of 5 could be maintained for 27 sec. and 10 for perhaps 5 to 8 sec.

Several interesting devices have been used by the EMW group to study combustion. Beck developed a water cooled pitot tube device for exploring the rocket jet, measuring gas composition, pressure and temperature. Details of these measurements have not been determined. A cooled tubular probe was also being made to investigate the inside of the combustion chamber in the same manner.

Many tests have been made with a fused quartz combustion chamber and venturi, 9" long by 3" in diameter giving about 5 kg. thrust. An explosion ended the career of this interesting device. Quartz windows have been used in otherwise normal combustion chambers.

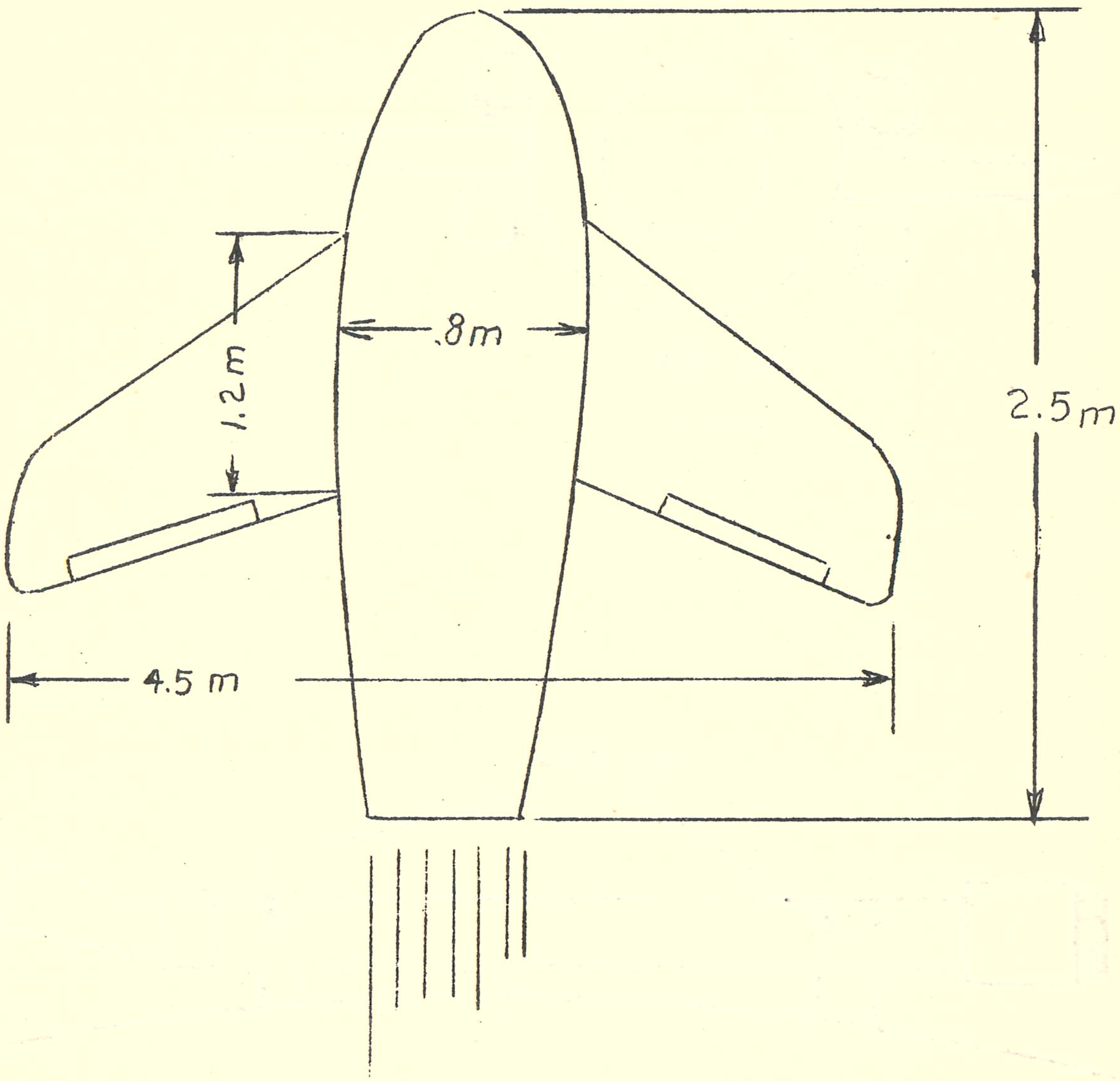
In general the German opinion is that with hypergoles very fine spray and mixing is not good but with monogols the spray should be as fine as possible. A monogol has never been used to cool a combustion chamber jacket.

Sponner, who has worked only with small monogole systems, has constructed ceramic combustion chambers and venturis. He has found that an alumina obtained under the trade name "steatic magnesia" (?) produces the best product. The powder plus a binder in water or water glass alone are pressed into a form. This pressing is then finished to shape, drilled, etc. and finally sintered.

Beck (now dead) has made an apparatus for measuring the jet velocity of a rocket motor. Schilling should know the details.

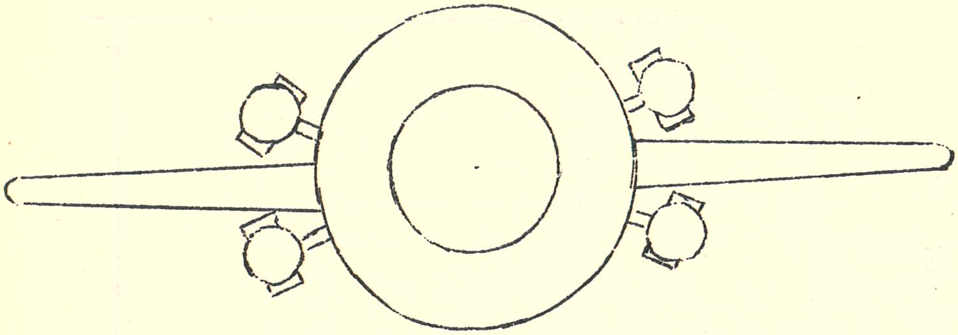
Another rocket reactant has been mentioned which is supposed to give a S.I. of 195 sec. Data is rather vague but it is supposed to have been developed by I.G., Leverkusen, made by the use of carbide and large quantities of H_2SO_4 and used in the Me 163. Chemically it is H_2O_2 + $KMnO_4$ + C_2H_5OH + Hydrozine hydrate.

Acknowledgement: The writers of this report are indebted to Lt. Ruwell and Lt. Harker, Ensign Gnau of Navy Tech. MiSU, Lt. Hochmuth, Ord. Tech. Intel. Team #9, and to Col. Cook's CIOS Team #163 for their cooperation in collecting information and apparatus.



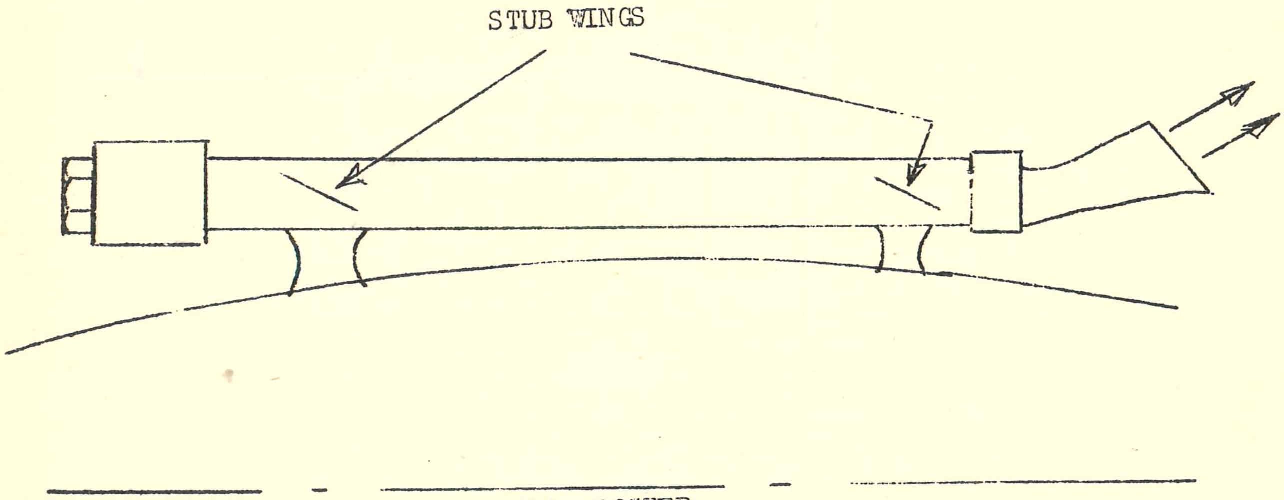
ENZIAN

FIG. 1



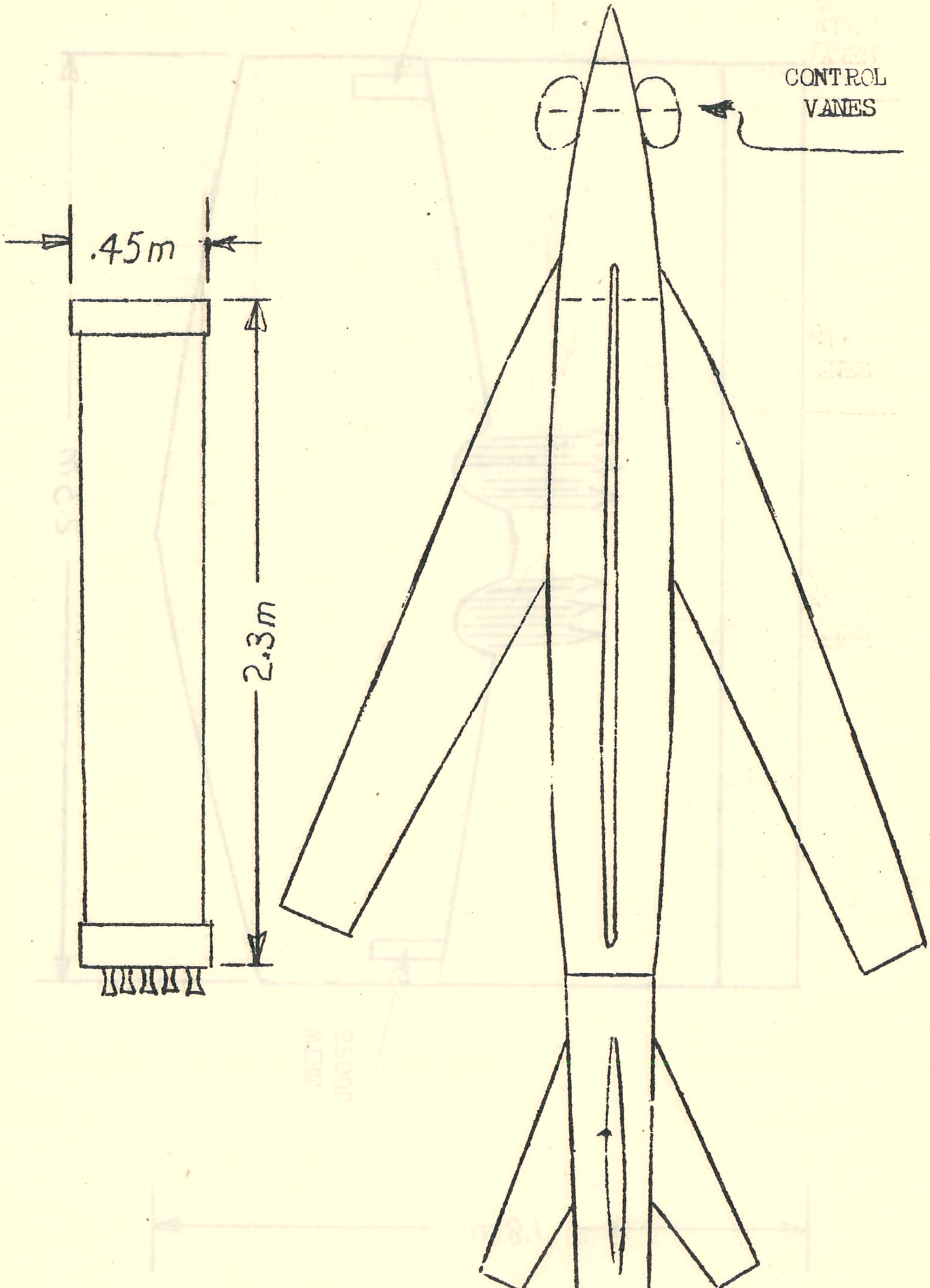
REAR VIEW

FIG. 2

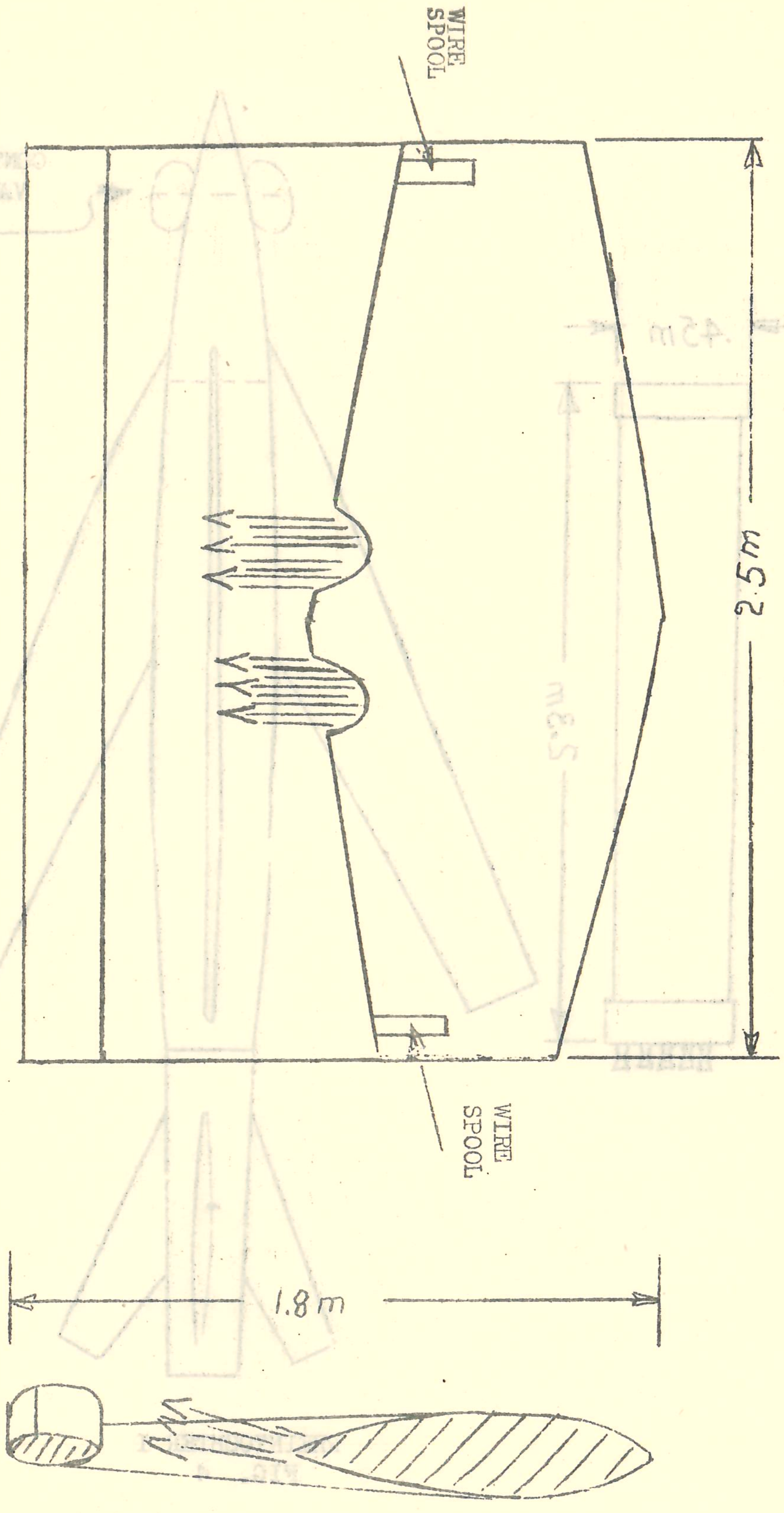


ENZIDN BOOSTER

FIG. 3



RHEINTOCHTER I
FIG. 4



ROTKAPPCHEN

FIG. 5

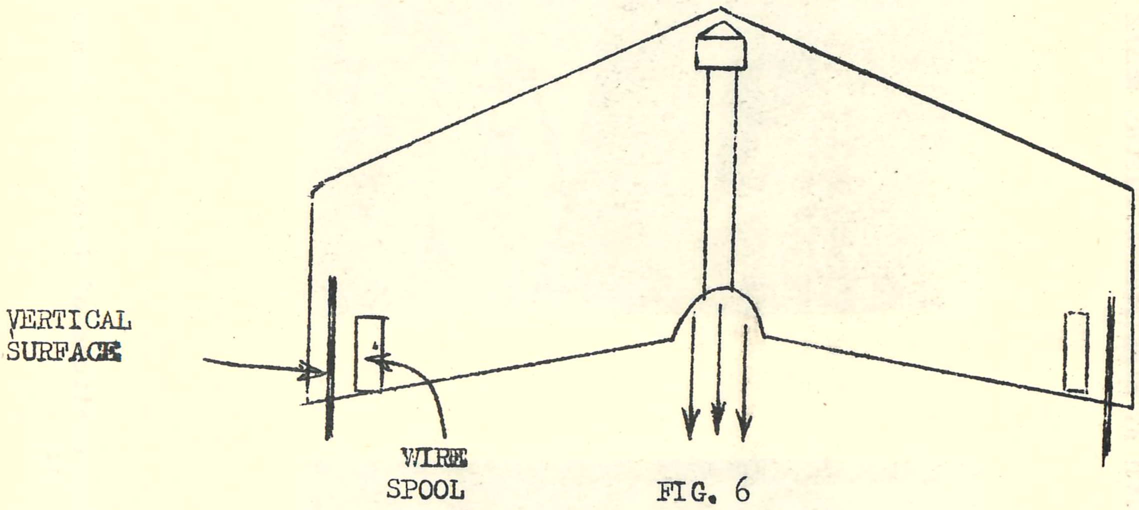


FIG. 6
ROCHEN

INVESTIGATION OF ROCKET RESEARCH AT ELEKTROMECHANISCHE WERKE G. m. b. H.

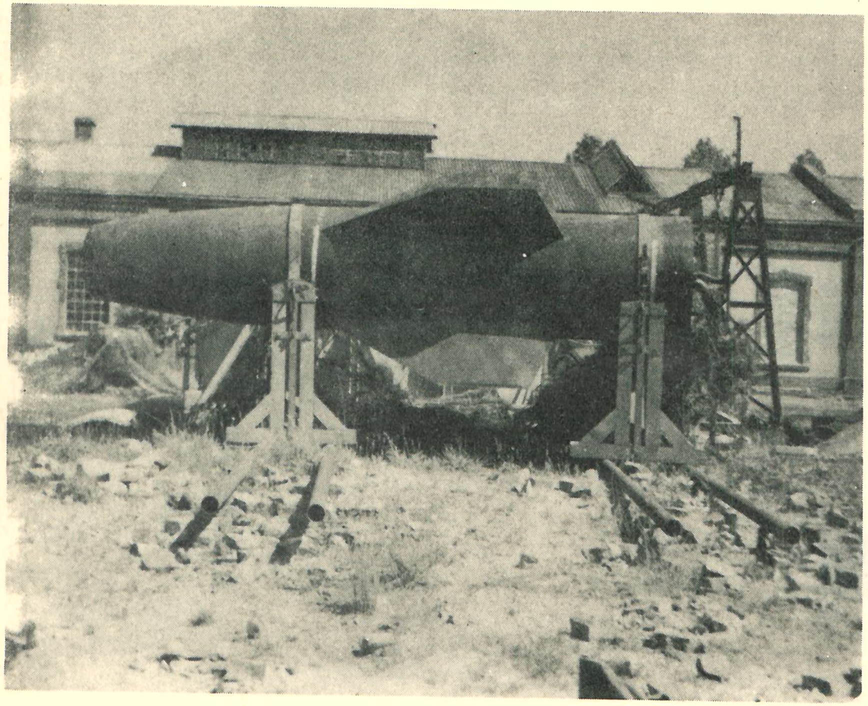


Photo No. 1

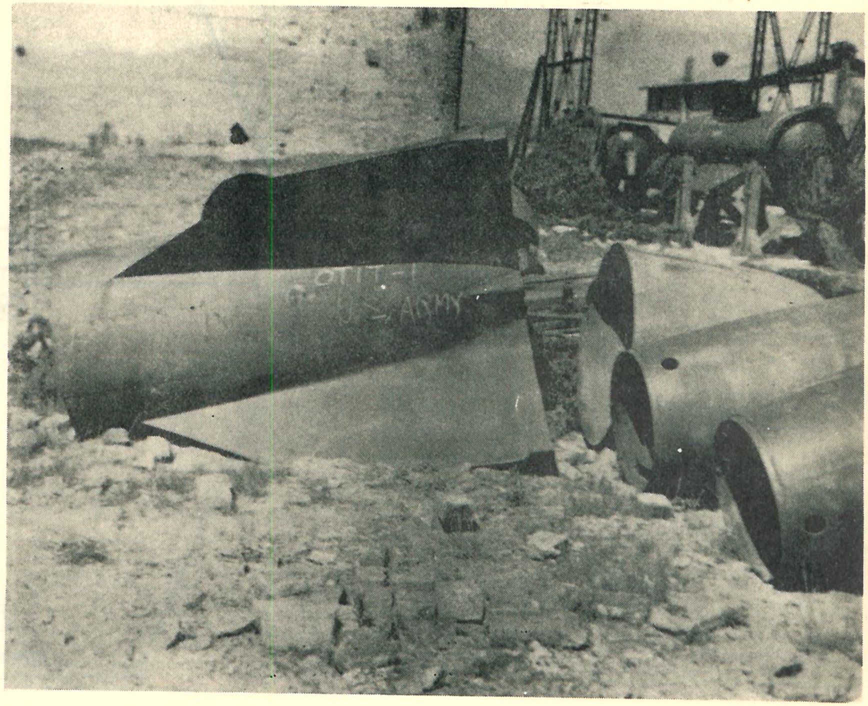


Photo No. 2

Photos No. 1 and 2 show the nose and tail sections of Wasserfall found at Neubleicherode.

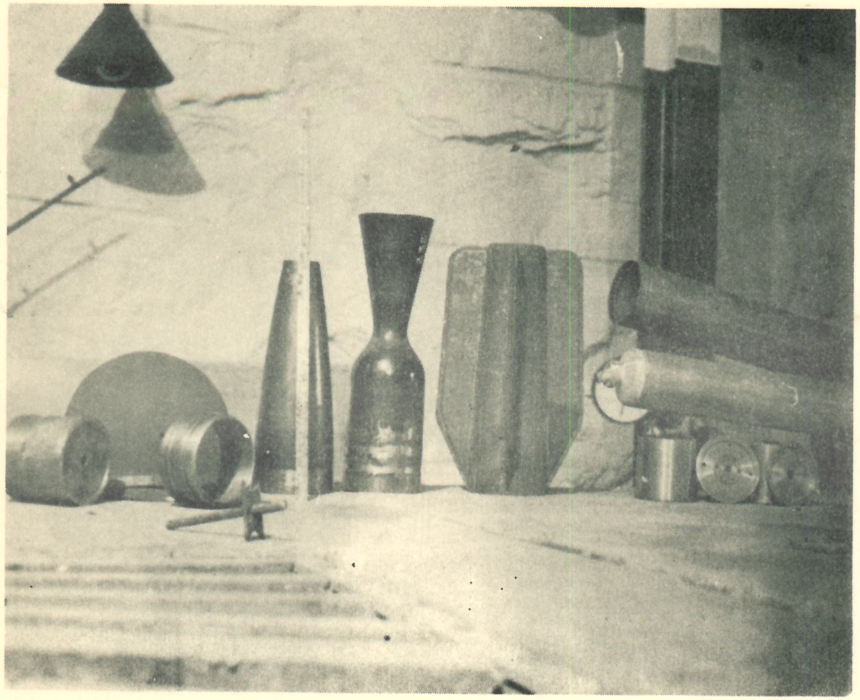


Photo No. 3

Photo No. 3 shows some of the parts of the larger Tyfun, liquid-propelled model. The tubes entering the picture from the right are the two concentric reactant tanks. These parts were found at the Mittlewerk tunnels at Niedersachswerfen.

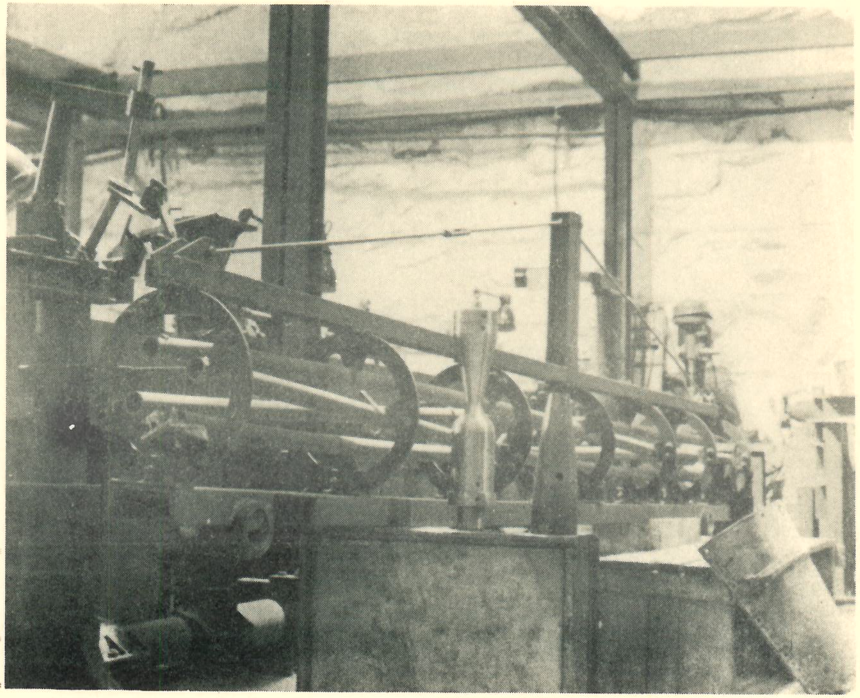


Photo No. 4

Photo No. 4 is a 100 cm. rocket-launching rack, possibly used early in the development of Tyfun. This view is from the breech end showing a retaining latch. The guide tubes are straight for four feet at the muzzle. This rack was also found in the Mittlewerk tunnels at Niedersachswerfen.