GENERAL SURVEY OF ROCKET MOTOR DEVELOPMENT IN GERMANY

I. Introduction.

(A) Statement of Activities.

The liquid propellant rocket motor development in Germany had been carried on by individual experimentors (i.e. Dr. Oberth) and technical groups until 1933 when the German Army became interested and set up a special department headed by Dr. Ing. N. C. Dornberger for the development of rockets for weapons of war. This organization originating at the Rocket Experimental Station in Berlin carried on its work through the medium of many governmental institutes and universities until 1936, when it was decided to set up an establishment for rocket development at Peenemünde, on the island of Usedom, which would be the clearing house for all rocket research and testing in Germany. The group originally called Heeresversuchsanstalt Peenemünde (HVP), later was called Hymat Artillery Park (HAP), and was divided into two sections, "East" for test beds and manufacturing facilities, under the direction of the Army; and "West", to handle flight testing of rocket missiles, JATO and rocket aircraft under the direction of the German Air Force. A special section of this establishment was formed, called the Elektromechanische Werke (EMW), whose primary purpose was to develop and manufacture the V-2 ground-to-ground rocket, C-2 or Wasserfall, an anti-aircraft rocket, and the Taifun, a non-controlled missile. Acceptance test of all missiles and rocket aircraft was done at Peenemünde although most of the power plant testing was done by the individual companies or institutions assigned to the problem.

Toward the end of the conflict, part of the EMW section moved to the Mittelwerke at Nordhausen to continue production of the V-2, Wasserfall and Taifun.

In 1936, Prof. Helmuth Walter set up his own company and was assigned the task of developing a power

LIST OF RESEARCH INSTITUTES[1] AND COMPANIES ENGAGED IN ROCKET DEVELOPMENT.

1. Aerodynamische Versuchsanstalt Goettingen (AVA)
   (Aerodymanic Research Institute)
   Aerodynamics, Theory of; Wind tunnel testing.

2. Deutsche Versuchsanstalt fur Luftfahrtforschung (DVL) Berlin- Alderhof
   (German Institute for Aircraft Research)
   Aerodynamics and Flight Characteristics.

3. Luftfahrt Forschungsanstalt (LFA), Brunswick
   (Hermann Goering Aircraft Institute)
   Fuels and Jets. Drs. Otto Lutz and Johannes Winkler. Dr. Braun on Feuerlillie, Aerodynamics and Windtunnel testing; rocket fuel and combustion chamber design.

4. Deutsche Versuchsanstalt fur Kraftfahrzeuge und Fahrzeuge Motoren, Berlin-Dresden (DVK)
   (The Automobile Institute)
   Drs. Beck and Conrad; A Technische Hochschule. Investigation of rocket power plants and various fuel systems.

5. Deutsche Forschungsanstalt fur Segelflug (DFS) Ainring
   (German Research Institute for Gliders)
   Investigated ramjets and flying wings. Dr. Lippisch also headed an institute of similar type in Vienna.

6. Luftfahrtforschungsanstalt Munich (LFM).
   Under the direction of Dr. Lutz of the LFA. This organization was comparitively new and was established for the purpose of concentrating on guided rocket missiles and ramjets.

[1] The Institutes are subordinates of the German Gov't.

7. Heeresversuchsanstalt - Peenemunde (HVP-HAP)
   Established on the island of Usedom on the Baltic Sea.
   Was later moved to Hartz Mountain area, then to
   Kochel and other sections in Southern Germany.
   Developed rockets V-2, Wasserfall and Taifun under
   section called Elektromechanische Werke (EMW).
   Windtunnel research on rocket powered missiles.

8. Helmuth Walter - Kiel (HWK), Headquarters Kiel;
   Plants at Lauban and Beerburg.
   Development of rocket and turbine power plants
   using H202 for Me-163, U-Boats, Torpedoes.
   Prof. Walter - Dr. Schmidt.

9. Bavarian Motor Works (BMW) Dr. Brueckmann
   Berlin-Spandau - Manufacturing
   Allach - Fuels and Testing
   Bruckmuehl - Manufacturing
   Development of spontaneous fuels Salbei and
   Tonka and rocket and turbine power plants for
   X-4, Hs-117, Schmetterling, Me-262, ATO, Me-163.

10. Wilhelm Schmidding - Bodenbach-Reichenberg.
    Manufacture of solid propellant motors.
    Also developed monopropellant "Myrol".

11. Rheinmetall-Borsig.
    Berlin-Tegel - Manufacturing
    Unterluss - Testing
    Work on one of the best solid propellant units.
    Developed the controlled missile "Rheintochter".

12. Messerschmidt AG.
    Regensburg - Production of Me-163 units.
    Oberammergau - Research on Enzian Missiles.

List of Research Institutes (cont'd)

13. Heinkel Aircraft Company - Jenbach and Stuttgart.
Manufacturers of aircraft engines, jet engines.
Parts production for Me-163 power plant for HWK.

14. Henschel Flugzeugwerke - Berlin - Dr. Wagner.
Developed and manufactured Hs missile series.

15. Gerhardt Fieseler Werke - Kassel.
Final development and manufacture of V-1.

16. Argus Motoren Werke - Berlin and Reineckendorf.
Development and manufacture of V-1 motor originally invented by Schmidt.

17. Westfaehlische-Anhaltische Sprenngstoff AG, (WASAG) Rheinsdorf on Elbe
Solid propellants and gunpowder.

18. Dynamit AG - Koeln-Troisdorf.
Warheads, solid propellants and coal fuel inserts for ramjets.

19. Buessing -Brunswick.
Research work on injection of N_2O (nitrous oxide) in Schmidt-Argus Rohr fuel.

20. Dipl. Ing. Friedrich Baron Doblhoff - Zell am See.
Development of jet helicopter using air blower.

21. Focke-Wulff - Ochsenhausen, near Ulm.
Helicopters and autogiros, Were designing a ramjet helicopter.

22. Hermann-Goering Steelworks - Heerte
Ramjets and ammonium nitrate monopropellants.

23. Wolff and Company.
Solid propellant ATO units.

There were numerous other firms with small rocket development groups. However, their work was usually similar to or subcontracted from those listed above.

2. Fuels.

(a) Rocket Fuel Development and Test Equipment.

There were four basic liquid fuel systems used in the German rocket development. These were generally known as the Hypergol, Katergol, Monergol and non-spontaneous bi-fuel systems. The non-hypergolen bi-fuel system such as liquid oxygen and hydrocarbons, preferably methanol, gave the best efficiency and was considered the simplest and easiest to handle. Hydrogen peroxide with a permanganate catalyst or nitrous oxide with a cobalt catalyst were put into the Katergol class. With the addition of B-stoff or hydrazin hydrate and M-stoff or methanol, hydrogen peroxide would be considered also in the spontaneous or Hypergolen group. With the addition of the hydrocarbon, an efficiency increase of 100% was noted. Nitric acid mixed with such chemical compounds as aniline, triethylamine and m-xylidines, was also in the Hypergolen class. The Monergol or monopropellant system forms the fourth group and closely resembles the Katergolen system. DEGN, a liquid used in the manufacture of the sold propellants, together with Myrol or methyl nitrate fall into this group. Nitro-methane apparently had not been considered seriously by the Germans.

Solid propellants such as diglycol and the castable powder Geissling were used for ATO, but since they are in a category of their own, they will not be considered in the liquid systems.

Oxygen gas burned with hydrocarbons such as methanol, gasoline, or oil was investigated as well as the use of Nitrous oxide as an oxygen carrier. Some of the highest efficiencies were effected from the combustion of these fuels, but none were used extensively in operations, the general trend being toward the Hypergolen system of nitric acid as the oxygen carrier because of the availability of both the acid and the hydrocarbons.

Fuels (a)(cont'd)

The Peenemunde group was primarily interested in Liquid Oxygen development, for use with the A-4 projectiles, and set up their own plant for its manufacture.

It was calculated that a specific impulse of 210 seconds or an exhaust velocity of 6720 feet/second could be attained with a water-alcohol mixture. On the test stand, however, they were able to reach a specific impulse of 220 seconds or an exhaust velocity of 7000 feet/second. For practical purposes it was found necessary to operate at a reduced efficiency of 197 seconds or a velocity of 6300 feet/second because of cooling difficulties, and differences in gas expansion between sea level and high altitudes. The nozzle design also had to be compromised so it was built for an exhaust pressure of 0.85 atm. absolute. With the exception of some highly experimental test work using gaseous oxygen and gasoline fuels, producing velocities of 8000 feet/second, the liquid oxygen power plants have produced consistently the highest efficiencies with the greatest degree of safety.

Aurol or hydrogen peroxide as a rocket propellant was developed by the Elektrochemische Werke in Munich and was sponsored by Professor Helmuth Walter who worked for the Armament Division of the German Government between 1930 and 1938. In late 1938 he established his own company known as the Helmuth Walter Kiel (HWK). Here he perfected this process not only for aircraft and assisted take-off devices, but also for use in U-boat turbine drives and torpedoes.

Hydrogen peroxide of 80% concentration and stabilized with phosphoric acid or oxyquinoline was known also as Aurel, Renal, Oxolin, Permalin, Subsidol, Neutrolin, Geprol and Ingolin. Some of these names were given the substance by Walter for his children. H_2O_2 was catalyzed by sodium permanganate (Z-stoff-N) or calcium permanganate (Z-stoff-C), Z-stoff-N for warm climates, and Z-stoff-C for cool areas. This mix produced approximately 37.6%

free oxygen and 62.4% H_2O in the form of steam at 500° C. In order to produce clean steam, free from manganese dioxide particles which would be harmful to turbine blading, it was found necessary to use solid catalysts. Th se catalysts were in t e form of pellets impregnated with MnO_2 or porcelain pebbles with a thin covering of MnO_2 and K_2CrO_4 (Potassium chromate), The second solid catalyst mentioned was called MP-14 and was used in the Me-163 power plant, and since the T-stoff was simply poured over the pebbles, this process could be repeated several times.

In the early stages of development, the cold motor method was used for both the ATO units and the Me-163-A power plant, as well as for rocket missiles. However, the efficiency was very low, the specific impulse being about 103 seconds or 3300 feet/second exhaust velocity. Therefore it was decided to introduce a hydrocarbon and hydrozin hydrate (acting as a catalyzer in place of the Z-stoff) in order utilise the free oxygen in the H_2O_2 reaction process. This combustion cycle brought the jet velocity up to 5800 feet/second with peaks as high as 6300 feet/second. With the increased combustion temperature it was found necessary to use regenerative type cooling of the nozzle and combustion chamber, as well as to introduce water into the C-stoff. The fuel mixture used in later models of the Me-163 consisted of 57% Methanol plus 30% hydrazon hydrate plus 13% water plus some additional catalyst.

There were three grades of hydrogen peroxide all about 80% concentration but with varying abounts of stabilizer depending on the degree of safety needed for handling and operating. TN-stoff was the standard grade and used generally in connection with rocket motor work. TS-stoff was processed more carefully, since it was to e used for U-boat turbines, but had about the same factor of stabilization as TN-stoff. The TS-stoff was lightly stabilized and generally used for torpedo uni s.

Walter built two types of jet assisted takeoff power plants (RI-203 and RI-209) using hydrogen peroxide and gasoline as the primary propellants with a specific impulse of 115 to 185 seconds. To obtain good ignition, B-stoff was injected into the combustion chamber ahead of the other fuels. As soon as the combustion cycle was complete, B-stoff was shut off and Z-stoff catalyst was allowed to continue feeding throughout the combustion period.

A tremendous amount of research and development work was done in Germany on the use of nitric acid or Salbei as an oxygen carrier with fuels which reacted spontaneously. It is believed that this vast amount of effort was prompted by the desire to find a fuel system which would be logistically simple and use fuels which could be produced synthetically, without danger to critical materials.

The Tonkas and Visols were the most important of these fuels and were comprised of amine and vinyl compounds.

The Tonkas were experimented with by the Bavarian Motor Works in Allach under the direction of their chief chemist, Dr. H. Hemesath. About 3000 combinations and mixtures were tried, the primary aim being to produce a fuel spontaneous with HNO_3, with a good viscosity-temperature characteristic, for use as an igniting chemical in their Me-163 power plant. It was found after numerous tests with this substance and gasoline that the Tonka was a good fuel base in itself.

The best Tonka developed, number 250, was composed of 50% by weight of $(C_2H_5)_3N$, triethylamine plus 50% by weight of commercial xylidines. The correct temperature-viscosity relationship could be held down to -40°C, the viscosity increasing rapidly below this temperature. It is interesting to note from their test work that the acid, not the Tonka, became critical at high temperatures causing vapor locks at 70°C. The theoretical mixture ratio was about 4.6 to 1 for complete oxidation, but the best operational range occurred at 4.2 to 1 with a slight excess of fuel. This ratio produced a specific impulse of 175 to 180 seconds or an exhaust velocity of approximately 5700 feet/second. In the development of these mixtures, it was necessary to hold the ignition delay down to 0.03-0.04 seconds since 0.06 seconds would cause violent detonation. These delays were accurately checked with a compact photo-electric comparison device which was situated so as to make flame-front comparisons.

Other experimental Tonkas were composed of compounds such as xylidines, anilines, optols, ethyl and methyl anilines with various mixtures of hydrocarbons such as gasoline or alcohol, alpha and beta pinenes and allyl amine compounds were also tested, and were spontaneous with Salbei.

A Tonka called 500 was developed for use in the controlled missile Hs-117 and consisted of:

12% M-Xylidine
10% aniline
10% optol
5% N-ethylaniline
8% N-methylaniline
35% Octane mixtures
20% benzine

Dr. Hemesath's group investigated the use of HC104 and H3PO4 mixed with 95% to 98% nitric acid, to cut down corrosion difficulties. It was found that a mixture of 90% HNO3 plus 10% HC104 with an addition of ½% H3PO4 could be stored for some time without causing decomposition.

Visol, another of the spontaneous fuel groups, was investigated by Dr. Lutz of the LFA in Braunschweig. The fuels were made up of vinyl compounds such as vinyl isobutyl ether, etc., and gave much the same results as in the devlelopment of the Tonkas. Visols however were of

Fuels (cont'd)

lower specific gravity and produced higher vapor pressures causing detonation in the combustion chamber. It is not possible to use this mixture with the amine compounds. It was possible, however, to mix 40% optol with 10% aniline and 50% Visol and was used in the Wasserfall rocket tests. This mixture with a specific gravity of 0.9 developed a specific impulse of 183 seconds. Other fuel experiments made by the Peenemunde group, gave a specific impulse of 214 seconds for a mixture of HNO_3 with optolene or Visol at a ratio of 4 to 1. It was found that a reduction to 204 seconds occurred when HNO_3 plus 10% H_2SO_4 was used. The LFA also investigated N_2O plus gasoline water mixtures with the help of Johannes Winkler. Mr. Winkler was actively engaged in the development of such rocket fuels as liquid oxygen, liquid methane, gasoline, liquid N_2O gasoline as well as investigations with various types of gaseous hydrocarbons with compressed air. The early N_2O experiments produced a high specific impulse of 190 seconds but due to overheating at the nozzle throat it was necessary to reduce the mixture ratio to 3 to 1 in the N_2O gasoline fuel system, which reduced the specific impulse to 168.

There was a certain amount of duplication of effort in connection with the fuel development in Germany since a number of organizations worked on their own fuel systems and were unaware at times of the results obtained by other organizations. This accounts for the multiplicity of names or generic terms for the same fuels.

Quality of rocket motor test beds and instrumentation used in German rocket development was on a par with the best test equipment in the United States. The majority of thrust and pressure measurements were made using Bourdon element gauges and recording by cameras.

The V-2 test beds although quite massive were very simply constructed, using weighing balances built by Suelz of Toledo. The V-2's were fired while supported

Fuels (cont'd)

vertically just above the ground, the exhaust passing over a series of tube gratings cooled with a water flow of 500 liters/min. A most extensive test establishment was set up by the BMW Company at Munich-Allach. Their testing area consisted of a long row of 21 cells, each opening into a court, where a large exhaust stack was available. When the test cells were used, portable ducts were connected from the cell openings to the stack, thus carrying off the exhaust gases. Each cell was equipped with manometers and reaction dynamometers for measuring thrust. The dynamometers were operated hydraulically and the indication was read on a Bourdon gauge. It was contemplated that magneto-striction gauges made by Siemens would be used for this purpose but were never installed. The BMW test installation provided several large cells for testing JATO motors as well as some small cells for fuel experiments. This installation was just being completed.

List of Experimental Fuels

	Classification	Name	20°C. Density	Spec. Imp.	Max. attained Jet Velocity	Oxid. used	Mix Ratio	Packing & Gaskets	REMARKS
1.	A-stoff	Liquid Oxygen	1.14	[illegible]	####	####	####	Igamit Buna	Used as an Oxygen carrier
2.	B-stoff	Hydrazin hydrate	1.03	###	###	####	####	Polyamid	Used as spontaneous ignitor of catalyst. h.h. 8% h2o
3.	Br-stoff	Reg. gasoline	.70	193	6200	A-stoff-h2o	3.5/1/2	Buna	
4.	C-stoff	B-stoff-M-stoff	.915	184	6900	T-stoff		Buna-s or Polyamid	Combination catalyst and hydro-carbon
5.	M-stoff	Methanol	.796	197	7040	A-stoff	1/.95	Buna	With A-stoff 75% M to 25% h2o Also mixed with B-stoff
6.	R-stoff	Tonka	.9	175-180	6000	Salbei	4.2/1	Lupolene	Consists of mix. of amine, anilines, and xylidine compounds-spontaneous.
7.	Sk-stoff Salbei-k	HNO3-catalyst	1.5	###	####	####	####		Also called salbei-k -- oxygen
8.	Sa-stoff MS-10 Salbei	HNO3-H2SO4	1.56	###	##	####	####	Chrome tanned leather.	Mix acid about 10% H2SO4-- carriers
9.	Sv-stoff	98% HNO3	1.6	###	####	####	####		Straight nitric acid --
10.	Tn-stoff	Hydrogen Peroxide Rockets	1.35	###	####	####	####	Polyethylene	80% H2O2+20% h2o+oxyquinolene as stabilizer-decomp.# less than 5
11.	Tasstoff	" " " " U-boats	1.35	###	####	####	####	"vinylchlor.	Phosporic acid as stabilizer decomposition # less than 1
12.	Tss-stoff	" " " " Torpedoes	1.35	###	####	####	####	" "	Stab. with 150mg/ltrs phos. acid decomp. # less than 5
13.	Z-stoff N	Sodium Permanganate	1.4	[illegible]	3450	T-stoff	16/1	No diff.	warm climate catalyst.
14.	Z-stoff C	Calcium " "	1.4	107	3450	" "	16/1	" "	Cold " " " "
15.	M-14 DP-18	U-boat and ME-163 solid catalysers	###	###	####	####	####		Porcelain stones of pellets covered with MnO2-K2CRO4 (Pot. chromate)
16.	Visol	Vinyl compounds	###	204	6500	Salbei-Sv	4.2/1		Example: Vinyl isobutyl ether
17.	Optolene	Visol and Optol	###	183	5850	Salbei	4/1		50%Visol-30%Optol-20% aniline
18.	Optol	Coal tar product	###	###	####	#####	####		Inhibits C4H4-contains phenol
19.	Fantol	Furfuryl alcohol	###	###	####	####	####		Used as ignitor with HNO3
20.	Helman	U-boat fuel	###	###	####	T-stoff	####		80%C2H5OH+30%(NH2)2+13%H2O+Catalyst
21.	Myrol	Methyl Nitrate							Monergol
22.	GM-1	Nitrous Oxide							Oxygen carrier
23.	Oil	Diesel oil	.88	247	7920	LOX or O2-gas	3.1/1		Test in water cooled motor. May have reached higher velocity.

Figure 1

3. Jet Assisted Take-off Systems (JATO)

The great majority of early experiments on liquid rocket motors were done to develop jet-assisted take-off units using liquid oxygen and operating for 10 to 30 seconds at 1000 to 3000 lbs. of thrust. These units were considered poor tactically by the German Air Ministry because of rapid evaporation of the liquid oxygen caused by lack of tank insulation.

Helmuth Walter, Kiel, developed and manufactured three types of JATO units using the H_2O_2 propellant system, namely: RI-201/109-500, RI-203/109-501, 502. The RI-201/109-500 delivered 1100 lbs. of thrust and operated on the cold motor principle with T-stoff and Z-stoff. The fuels were mixed in a special compartment in the combustion chamber which led to the nozzle. The total weight of this unit with the parachute was about 1000 lbs. The RI-203 units were similar in every respect, except for motor thrust, one having 1000 lbs. more thrust than the other, but less running time. These units operated on the hot system where hydrozin hydrate is injected into the combustion chamber with T-stoff for initial combustion or starting, followed by gasoline with the reaction being maintained by catalyzation with Z-stoff. An electric detonating type of frangible disc valve was used for starting the high pressure flow, which in turn pressurized the tanks and supplied control pressure.

BMW developed two JATO units: one, Model 109-718, (Figures 3 and 4) with pumps attached to the BMW 003 Turbojet for installation on the Me-262 airplane; the other, a pressure unit called RI-301, (Figure 2). The pumps for the 109-718 units were driven by an extension shaft from the accessory drive of the 003 Turbojet. The fuel was pumped from the tanks in the fuselage with a novel type of centrifugal pump using a Venturi at the inlet with an impeller wheel consisting of three triangular shaped vanes, instead of the usual spiral flow blade (Figure 5). Pressure from the aircraft hydraulic system was imposed on the main propellant valves through an electric solenoid valve which forced them open against the pump feed pressure. Ignition was spontaneous and the motor could be started and stopped at will although an electric powder squib was considered necessary to prevent hard starts during the operations, a pressure regulator, which by-passed part of the propellant, was installed in each line ahead of the main propellant valves, and could be set for any desired pressure (Figure 6). HWK also built a JATO unit for the Me-262 patterned after the Me-163 power plant, called the RH-211 but it is not known whether this unit was ever tested.

There were numerous solid propellant ATO units of various sizes, manufactured by Rheinmetall-Borsig, Wasag, Wolff and Company as well as both the liquid and solid units by Wilhelm Schmidding Co. It is believed that these solid units were more widely used than the liquid power units. Their running time was 10 to 12 seconds maximum, at thrust ranges up to 3300 lbs.

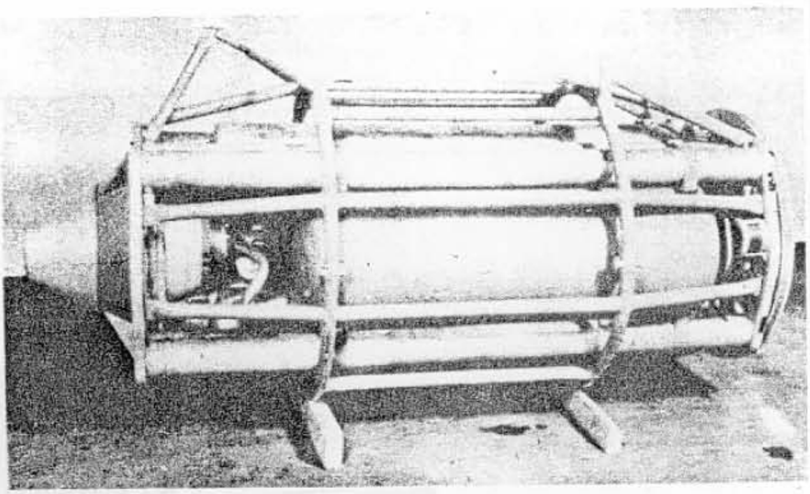


Figure 2. BMW Jet assisted take off unit - RI-301

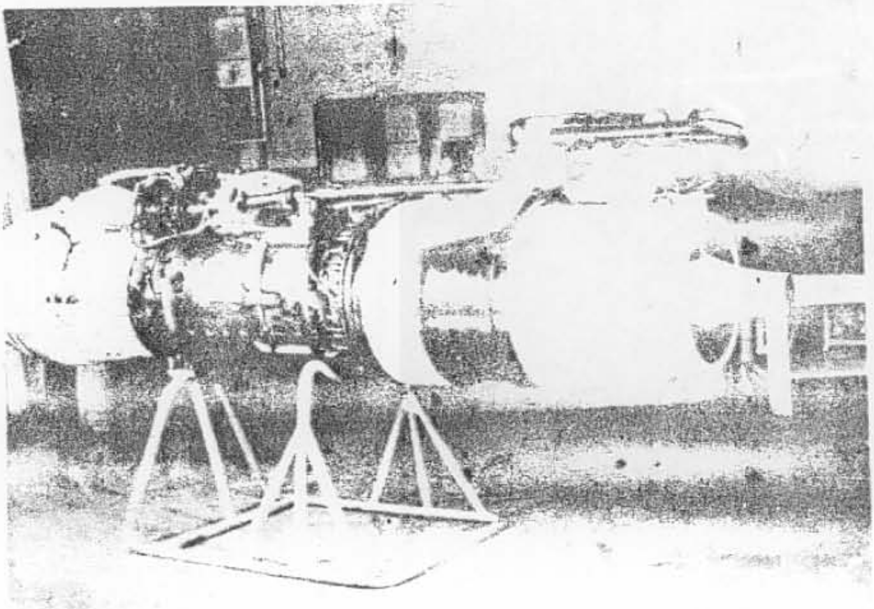


Figure 5. JATO BMW 109-718 mounted on BMW 003
Turbojet engine.

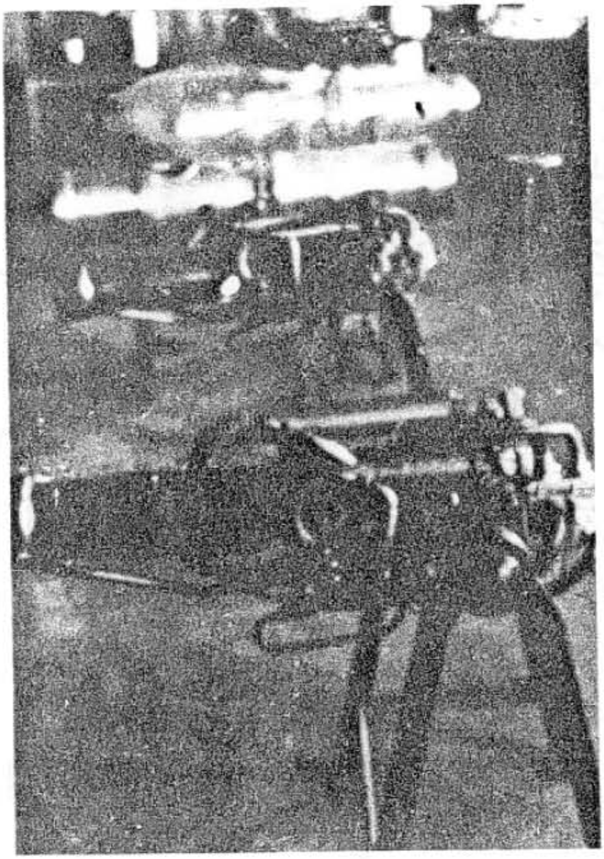
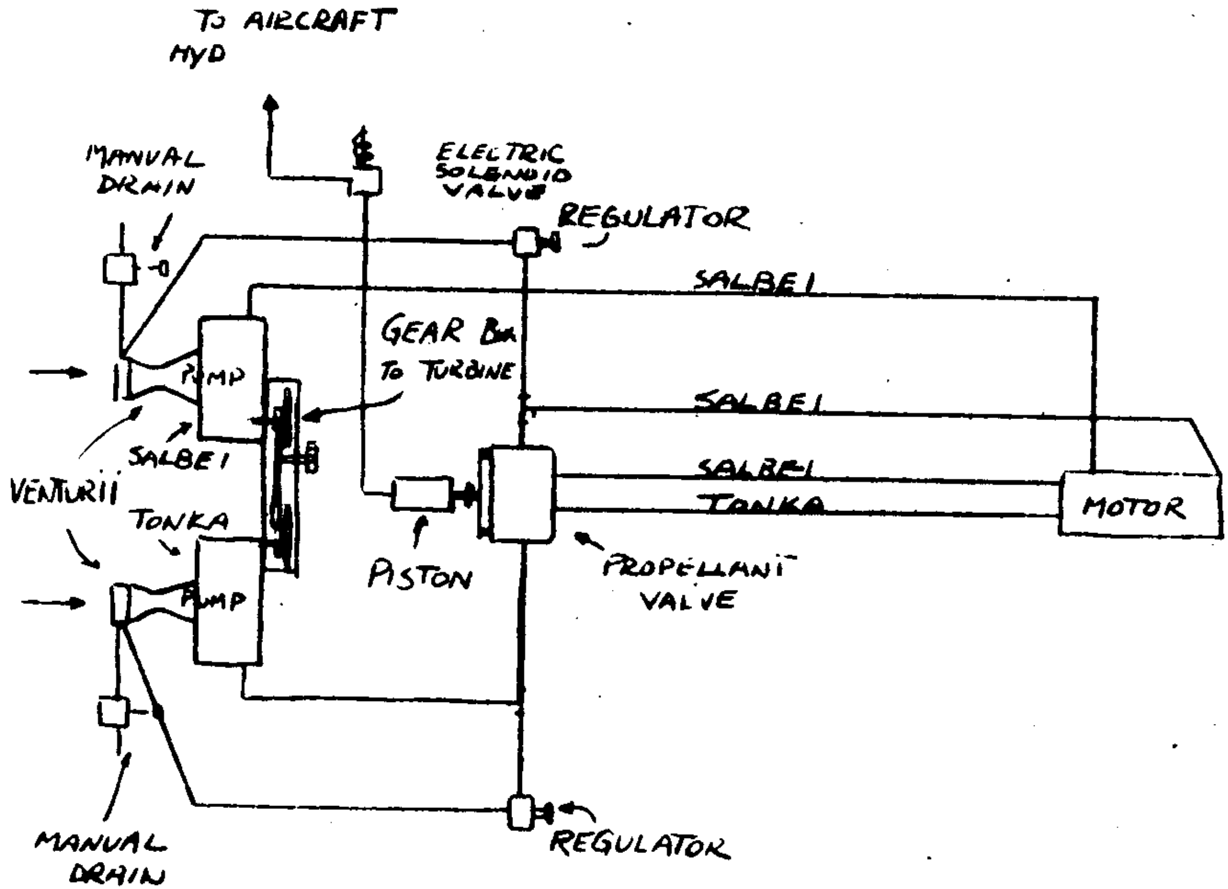


Figure 4. BMW 109-718 JATO for Me-262
HS-117 tanks in background.



JATO
BMW 109-718
FIGURE. 5

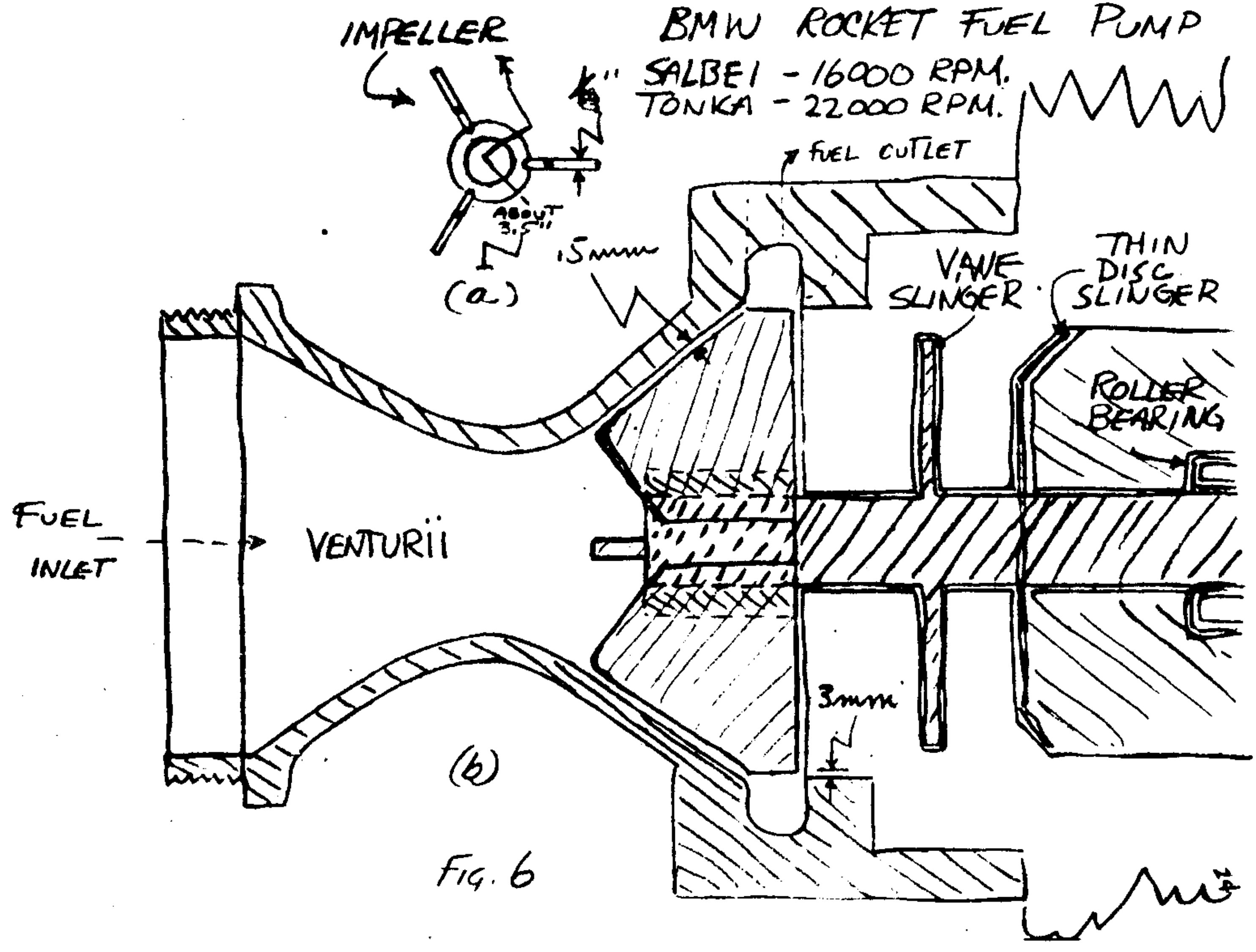

BMW ROCKET FUEL PUMP
SALBEI - 16000 RPM.
TONKA - 22000 RPM.
IMPELLER
ABOUT 3.5"
(a)
.5mm
FUEL OUTLET
VANE SLINGER
THIN DISC SLINGER
ROLLER BEARING
FUEL INLET
VENTURII
3mm
(b)

Fig. 6

JATO UNIT

Motr No. RI-201/109-500

Company	HWK
Location	Kiel
Use	Assisted take off for He-111, etc.
Design	X
Thrust	1100 lbs.
Time	30 sec.
Propellant Rate	23 lbs/sec
Oxidizer	T-stoff
Fuel	Z-stoff
Jet Velocity	3200 ft/sec.
Bottle Pressure	1800 lbs/sq. inch compressed air
Tank Pressure	600 lbs/sq. inch approx.
Chamber Pressure	270 lbs/sq. inch
Dry Weight	X
Specific Impulse	100
Total Impulse	33,000 lbs/sec.
Velocity	X
References	X

Remarks: One of the earliest Walter JATO units. About 150-200 were manufactured.

JATO

Motor No. RI-203/109-501

Company	HWK
Location	Kiel
Use BV 138, DO-18.	Assisted take off for He 111, Ju 88,
Design	Helmuth Walter
Thrust	2200 lbs.
Time	42.5 sec.
Propellant Rate	12.9 lbs/sec.
Oxidiser	T-stoff - 486 lbs.
Fuel	Gasoline - 37.lbs; Z-stoff 24 lbs.
Jet Velocity	5500 ft/sec.
Bottle Pressure	2250 lbs/sq. inch.
Tank Pressure	X
Chamber Pressure	300 lbs/sq. inch.
Dry Weight	500 lbs.
Specific Impulse	172
Total Impulse	93,550 lbs/sec.
Velocity	X
References	HWK Handbook

Remarks: Ignition with B-stoff injected into chamber before Z-stoff to give good ignition and to prevent hard starts (1.06 lbs).

JATO

Motor No. RI-209/109-502

Company	HWK
Location	Kiel
Use	Assisted take off for He 111, Ju 88, BV 138 and Do 18.
Design	Helmuth Walter and Dr. Schmidt
Thrust	3300 lbs.
Time	3 0 sec.
Propellant Rate	18 lbs/sec.
Oxidiser	T-stoff-486 lbs.
Fuel	Gasoline - 37 lbs; Z-stoff - 24 lbs.
Jet Velocity	5750 ft/sec.
Bottle Pressure	2250 lbs/sq. inch.
Tank Pressure	X
Chamber Pressure	320 lbs/sq. inch
Dry Weight	500 lbs.
Specific Impulse	180
Total Impulse	99,000 lbs/sec.
Velocity	X
References	X
Remarks:	Ignition and general running operation identical with RI-203. (See Figure 1).

JATO

Motor No. 109-718

Company	BMW
Location	Allach and Bruckmuhl near Munich
Use	Assisted Take Off for Me 262.
Design	
Thrust	1320 lbs. to 2750 lbs; 112 sec. full thrust.
Time	3 minutes
Propellant Rate	15.6 lbs/sec.
Oxidiser	Salbei) 3520 lbs for 2 motors (mix ratio 4.2:1)
Fuel	R-stoff)
Jet Velocity	5750 ft/sec.
Bottle Pressure	Pumps driven by jet turbine
Tank Pressure	Pump feed pressure 600 lbs/sq. inch
Chamber Pressure	525 lbs/sq. inch
Dry Weight	176 lbs. each unit
Specific Impulse	180
Total Impulse	X
Velocity	X

References Dr. Clapp's report, Army Technical Intelligence Section.

Remarks: This JATO unit was designed for use with the Me 262 jet airplane. Two units were used, the pumps being driven by gear drive from jet turbine engines on the aircraft. JATO units could be started while gas turbines were operating. Salbei pump at 16,000 RPM - Tonka 22,000 RPM at full thrust. (See Figure 4).

4. AIRCRAFT ROCKET POWER PLANTS

The most important liquid propellant rocket motors for aircraft were developed by the Helmuth Walter Company in Kiel. These power plants were an outgrowth of the HWK jet assisted take off units and were especially designed for use in the Me-163 high speed interceptor.

There were three phases of development and about seven models, namely:

RII-203 - First pump unit, cold motor.
109-509A - Hot Motor, increased thrust.
109-509B Hot motor with small cruising motor.

Model RII-203 developed 440-1650 lbs of thrust and had its first flight tests in 1941. The results of these tests were encouraging but the efficiency was so low that it was of little practical value for combat. For this reason the Walter Company changed to the hot motor system. They injected hydrazin hydrate and methanel which increased the efficiency by 100%. The 109-509A series using this fuel system was put into production in 1943. The 109-509A motor consisted of a turbine driven by T-stoff, using a solid catalyzer steam pot and was started with an electric motor. The starter would bring the pumps up to 6 atm, which was sufficient to cause T-stoff to feed into the pot to maintain 20 atm. of pressure. When power was desired, a second position on the starter lever would cut in the pump governor, which would allow the pot pressure to build up to 26 atm at maximum thrust. The starting lever was mechanically connected with the throttle and main propellant valves. The throttling was accomplished by valving into three sets of injectors. The first two sets had 3 jets in each set, the last set had 6 jets. This method of throttling was of definite assistants in maintaining high fuel economy at low thrust. The 109-509A-2 was envolved from the AO-1 because of difficulties encountered with hard starts, pump cavitation at quick changes of acceleration, and delays with the electric starter. It is believed that this unit was never flight tested. The starter difficulty was corrected by adding a small tank containing T-stoff which fed by gravity to the steam pot. The hard starting problem was solved by tapping live steam from the steam purge line and preheating the C-stoff in the first throttle stage. Steam ejectors were then installed on the pressure side of both pump lines for the purpose of drawing out air bubbles. The ejector was installed with internal check valves which were adjustable and blocked the function of the ejector unless the pump feed pressure fell below the presetting. The thrust was also increased 40 lbs. It was decided that a cruising motor should be added to the power plant to bring up the fuel economy, thus increasing the range of the aircraft. This motor would deliver approximately 800 lbs. thrust. The small cruising motor was installed on the 109-509 A-1 and given the number 109-509B. The B power plant main motor thrust was increased to 4400 lbs. max. The results were promising and a unit called 109-509C was finally built and tested incorporating all the best features in the previous power plants. (See Figure 7).

In an interview with Dr. Lippisch, designer of the various Me 163 airplanes, it was found that numerous difficulties were encountered with leakage and explosions in flight. Fires were caused by H2O2 leakage mixing with oil used on the landing skids. It was his general opinion that ejector pumps should also be installed in fuel tanks to prevent cavitation, and suggested that Zoborowski of BMW had designed a very good pump for this purpose.

During the period of HWK motor development, the BMW Company was requested to develop a motor of similar design for the Me163 plane but to use Salbei and Tonka fuels. Fifty power plants were built according to the BMW officials but were not completed in time for flight testing.

This power plant was the forerunner of the 109-718 ATO unit mentioned previously but operated from its own turbine drive. All of the documents at the BMW plant were destroyed but as far as can be ascertained this unit was similar in every respect to the 718 but used a hydraulic control on the main propellant valve for throttling purposes. A Salbei-Tonka firepot was experimented with for driving the turbine but the leakage and corrosion diffi--culties were so great that the Walter T-Stoff steam pot had to be used in the final design.

It was believed that these pumps and injectors were superior to the Walter units and were expected to give less cavitation difficulty.

DFS 194

(Early Me-163 Motor RI --)

Company	Helmuth Walter Kiel
Location	Kiel
Use	Power plant for high speed test plane
Design	Messerschmitt - Dr. Lippisch
Thrust	770 lbs.
Time	X
Propellant Rate	7.4 lbs/sec.
Oxidizer	T-stoff
Fuel	Z-stoff
Jet Velocity	3400 ft/sec.
Bottle Pressure	Pumps T-stoff and solid catalyst
Tank Pressure	Pump feed about 500-600 lbs/sq.inch
Chamber Pressure	270 lbs/sq.inch
Dry Weight	X
Specific Impulse	106
Total Impulse	X
Velocity	X
References	Dr. Lippisch.

Remarks: The DFS-194 aircraft was the first unit test flown and was the forerunner of the Me 163. This plane was originally planned by the DFS in Berlin and was designed by Dr. Lippisch at the Messerschmitt Company.

Company	HWK
Location	Kiel
Use	Second model Me-163-A High Speed fighter
Design	Dr. Lippisch at Messerschmitt
Thrust	440-1650 lbs.
Time	X
Propellant Rate	15.7 lbs/sec at full thrust
Oxidizer	T-stoff
Fuel	Z-stoff-C
Jet Velocity	3400 ft/sec.
Bottle Pressure	Pumps with electric motor starter
Tank Pressure	600 lbs/sq. inch pump feed pressure
Chamber Pressure	270 lbs/sq. inch
Dry Weight	167 lbs.
Specific Impulse	106
Total Impulse	X
Velocity	X
References	U.S. Naval Technical Mission in Europe Technical Report No. 134-45.
Remarks:	Flight tested in late 1941.

ME-163

Motor No. 109-509 A-0-1

Company	HWK	
Location	Kiel	
Use	Power plant for Me-163 B-0	
Design	Messerschmitt	
Thrust	660-3300 lbs.	
Time	15-20 min. max. (full thrust 4 min 11 sec)	
Propellant Rate	17.5 lbs./sec. full thrust	
Oxodizer	T-stoff)	) 4400 lbs. total fuel
Fuel	C-stoff)	
Jet Velocity	5800 ft/sec.	
Bottle Pressure	600 lbs./sq.inch	
Tank Pressure	Pump Feed - electric motor starter	
Chamber Pressure	300 lbs./sq.inch	
Dry Weight	368.5 lbs.	
Specific Impulse	181	
Total Impulse	X	
Velocity	X	
References	U.S. Naval Technical Mission in Europe Technical Report No. 134-45.	

Remarks: About 300 A-1 motors manufactured. This was the first model to use the hot motor system with regenerative cooling. Hydrazin hydrate and methanol with H20 were mixed. This unit was very susceptible to cavitation in the pumps and would start very hard. The plane with this motor can reach an altitude of 6 miles in 3 minutes at max. climb angle of 40 degrees.

ME-163

109-509 A-2

Company	HWK
Location	Kiel
Use	For Me163 B-0
Design	Messerschmitt - Dr. Lippisch
Thrust	3740 lbs increased; 440 lbs above 109-509-A-1
Time	15-20 min. max.
Propellant Rate	20.8 lbs./sec.
Oxidizer	T-stoff
Fuel	C-stoff
Jet Velocity	5800 ft./sec.
Bottle Pressure	600 lbs. pump feed - T-stoff starter
Tank Pressure	Solid catalyst plus T-stoff
Chamber Pressure	320 lbs./sq.inch
Dry Weight	368 lbs.
Specific Impulse	181
Total Impulse	X
Velocity	X
References	U. S. Naval Technical Mission in Europe Technical Report No. 134-45.

ME-163, 109-509 A-2 (cont'd)

Remarks: Trouble with hard starts practically corrected by the addition of steam jacket around 1st throttle stage of C-stoff. Ejectors were installed to assist in preventing cavitation and to prevent air traps in propellant lines.

NATTER HP-20

Motor No. 109-509-A-2

Company	HWK
Location	Kiel
Use	Piloted rocket interceptor
Design	Fieseler Aircraft. Mfd. by Eric Bachen at Waldsee
Thrust	330 lbs to 3740 lbs.
Time	120 sec; full thrust 64 sec.
Propellant Rate	20.6 lbs./sec.: full thrust includes pump fuel
Oxidizer	T-stoff, 450 liters
Fuel	C-stoff - 250 liters
Jet Velocity	5830 ft./sec.
Bottle Pressure	Pumps
Tank Pressure	600 lbs./sq.inch at pump outlets at full thrust
Chamber Pressure	300 lbs./sq.inch
Dry Weight	368 lbs.
Specific Impulse	181
Total Impulse	239, 360 lb/sec.
Velocity	cruising 480 miles/hour
References	Assessment Report 150, USSTAF.

NATTER HP-20, Motor No. 109-509-A-2 (cont'd)

Remarks: One or two units were tested. Max. altitude of 12,000 feet with operational radius of 12 miles. This unit was launched with two SR-34 ATO units delivering 2200 lbs. for 12 sec. and weigh 33 lbs. each.

ME-163

109-509-B-1

Company	HWK
Location	Kiel
Use	For Me-163-B-1
Design	Messerschmitt
Thrust	880 lbs to 4400 lbs small cruising motor of 836 lbs.
Time	15-20 min. max.
Propellant Rate	24.4 lbs/sec. at full thrust of 4400 lbs.
Oxidizer	T-stoff
Fuel	C-stoff
Jet Velocity	5800 ft/sec.
Bottle Pressure	Pumps with electric starter
Tank Pressure	at 600 lbs/ sq. in.
Chamber Pressure	320 lbs/sq. in.
Dry Weight	425 lbs approx.
Specific Impulse	181
Total Impulse	X
Velocity	X
References	X

Remarks! Increased main motor thrust 660 lbs and addition of cruising motor effected. Unit actually was old A-1 motor changed.

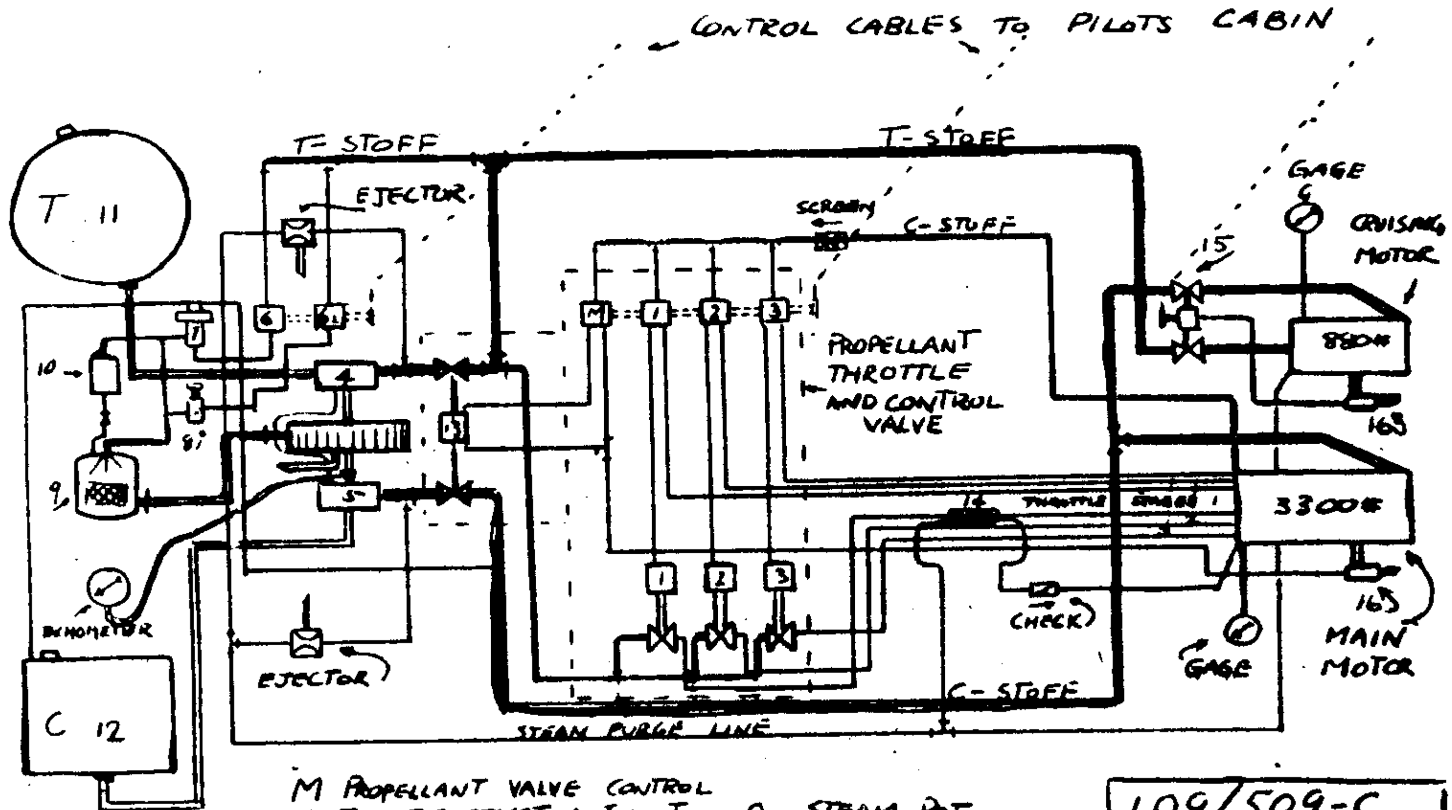
ME-163

109-509C

Company	HWK
Location	Kiel
Use	Experimental motor was not flight tested.
Design	X
Thrust	4400 lbs max. large unit; 880 lbs cruising motor.
Time	X
Propellant Rate	24.4 lbs/sec. at full thrust of 4400 lbs.
Oxidizer	T-stoff
Fuel	C-stoff
Jet Velocity	5800 ft/sec.
Bottle Pressure	Pumps with T-stoff starter
Tank Pressure	600 lbs/sq. inch
Chamber Pressure	320 lbs/sq. inch
Dry Weight	About 400 lbs
Specific Impulse	181
Total Impulse	X
Velocity	X

References: U.S. Naval Technical Mission in in Europe Technical Report No. 134-45.

Remarks: Latest development, combining good qualities of A and B units. about two or three of these units were built. (see figure 2).



M PROPELLANT VALVE CONTROL
1 THROTTLE STAGE I to INJ I
2 " " STAGE II to " II
3 " STAGE III to " III
4 T-STOFF PUMP
5 C-STOFF PUMP
6,-2 STEAM POT CONTROL
7 STEAM POT GOVERNOR
8 STEAM POT IDLER
9 STEAM POT
10 STEAM POT STARTER TANK
11 T-STOFF TANK
12 C-STOFF TANK
13 PROPELLANT VALVE
14 I STAGE C-STOFF HEATER
15 CRUISING MOTOR PROP VALVE
16 JACKET VENTS

109/509-C
ME-163 MOTOR

FIGURE 7

ME-163

BMW 3390A - R II 303

Company	BMW
Location	Allach
Use	Power plant for Me 163
Design	Requested by Dr Lippisch in 1943; due to HWK motor difficulties.
Thrust	440 lbs. to 3300 lbs.
Time	8-15 minutes
Propellant Rate	18.3 lbs/sec.
Oxidizer	Salbei
Fuel	Methanol - Total propellant wt. - 4070 lbs; tonka used for ignition
Jet Velocity	5600 ft/sec.
Bottle Pressure	Gas turbine using Salbei M-stoff-water
Tank Pressure	600 lbs/sq. in.
Chamber Pressure	500 lbs/sq. in.
Dry Weight	X
Specific Impulse	175
Total Impulse	X
Velocity	X
References	X

Remarks: About 30 units were built and tested at Allach. Difficulty was experienced with turbine drive for pumps and tests were made with Walter turbine and gas generators using BMW pumps. Thrust controlled hydraulically by chamber pressure. Tonka ignition started with small electric motor driven pump. (see figure 3).

5. ROCKET MOTORS FOR GUIDED MISSILES

The following sheets list the operating characteristics of the most important rocket motors for guided missiles in operation or under development in Germany. No attempt will be made to describe the missile or its control system since the U.S. Naval Technical Mission in Europe is at present compiling a complete detailed report on the status of each unit as of 1945.

The operating characteristics are those actually observed in flight or shown in final test bed data before flight. Some of these power plants developed higher efficiencies during the preliminary stages of test work but due to cooling problems or variations in acceleration and range of the missiles, it was found necessary to operate them at lower temperatures and lower efficiencies.

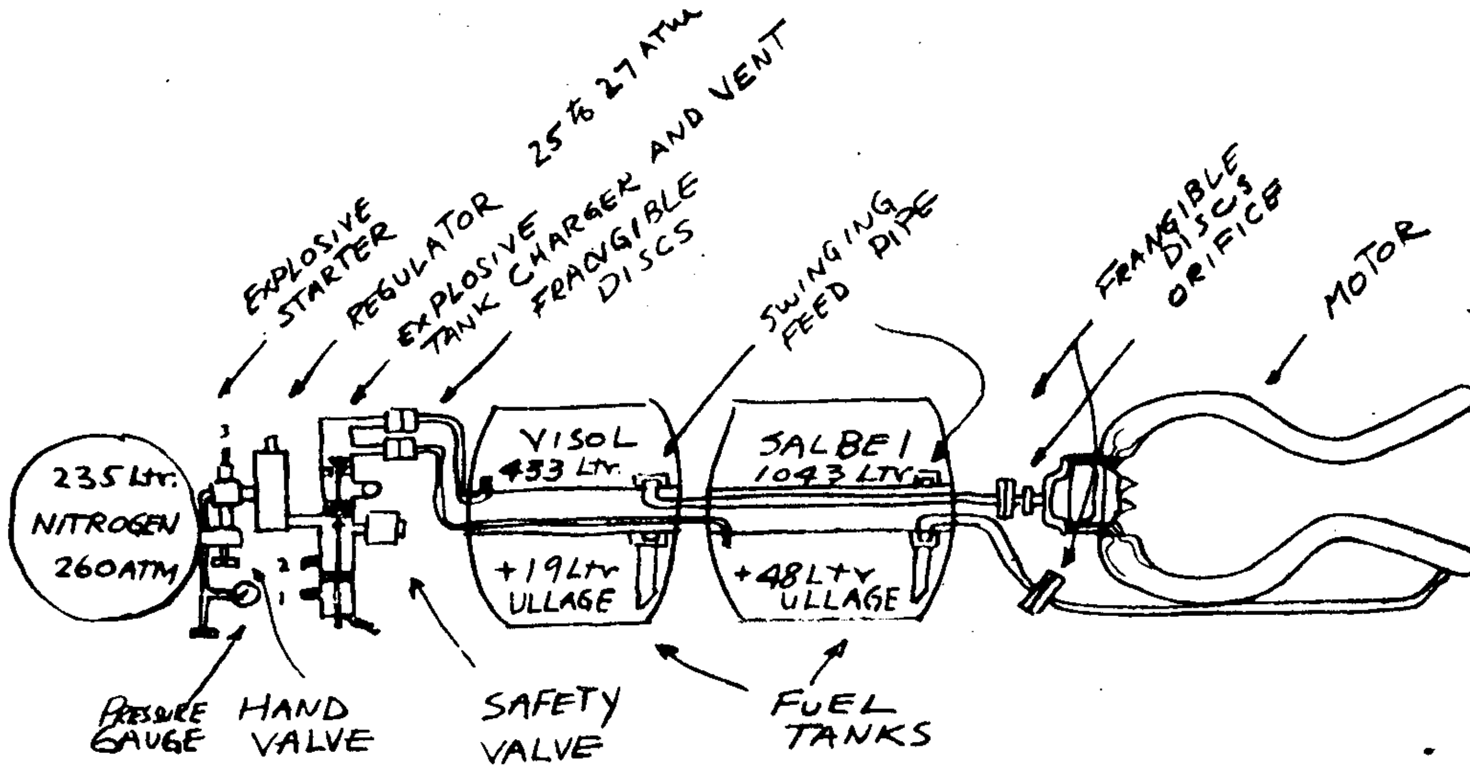
The important feature noted in all of these power plants with the exception of the A-4 rocket is the simplicity of the valving and starting mechanisms. Nearly all of the units used the pressurized system with electrical bursting discs to start the feed pressure to the tanks.

The main propellant valves usually consisted of frangible metal discs which burst when tanks were nearly up to pressure. Flexible hoses inside the propellant tanks assured maximum fuel withdrawal.

ROCKET POWER PLANT FOR THE WASSERFALL

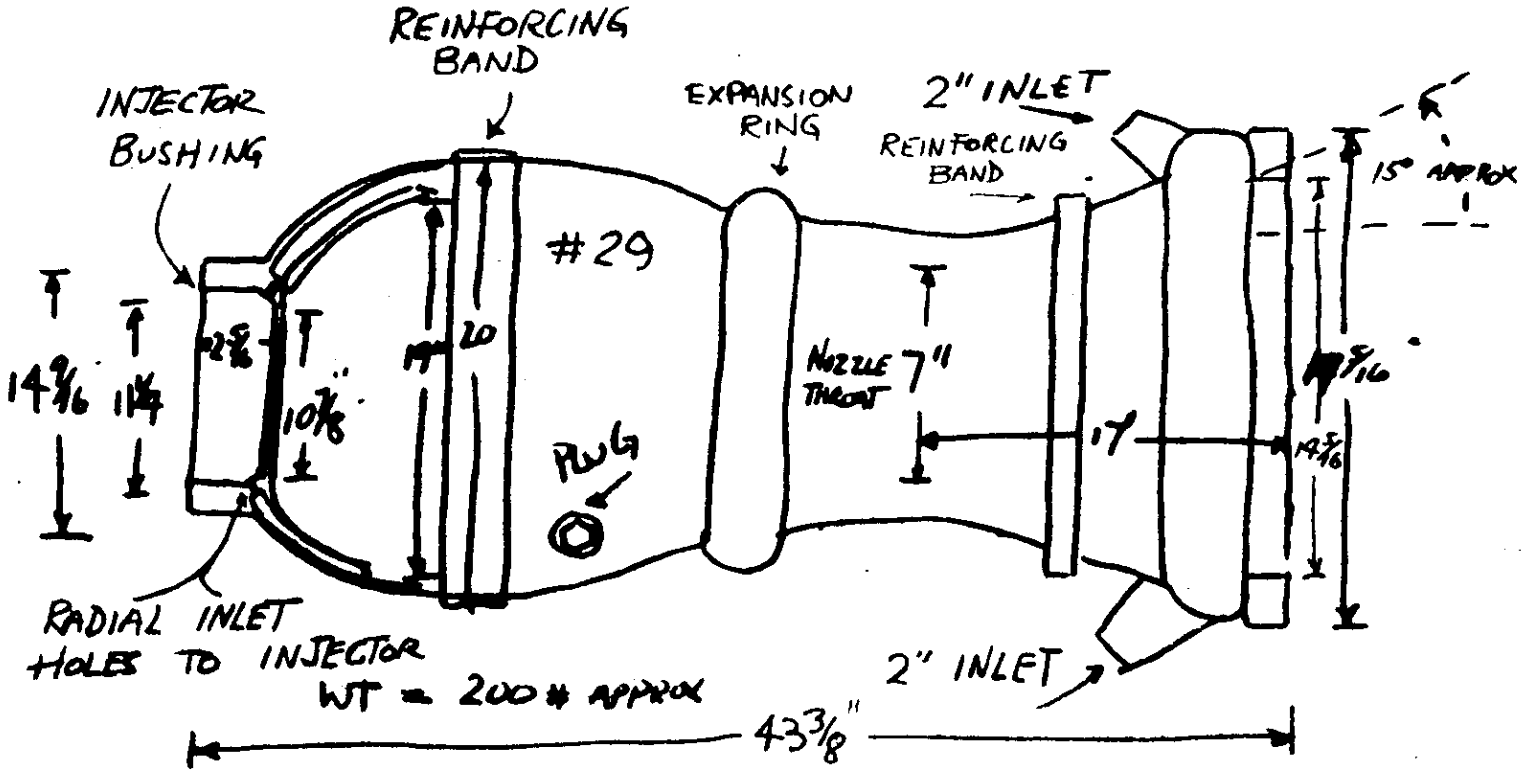
Company	Peenemunde
Location	Peenemunde
Use	Flak rocket
Design	Oberleutnant Schonfolder, under Air Ministry.
Thrust	17,500 lbs; actual 17160 lbs.
Time	45 sec; actual 40-42 sec.
Propellant Rate	96.8 lbs/sec.
Oxidizer	Salbei or MS-10 - 3317 lbs.
Fuel	visol or optolene - 994 lbs.
Jet Velocity	5800 ft/sec.
Bottle Pressure	3900 lbs/sq. in; - 154 lbs, N_2
Tank Pressure	400 lbs/sq. in.
Chamber Pressure	220 lbs/sq. inch
Dry Weight	3872 lbs.
Specific Impulse	180
Total Impulse	686,000 lbs. sec.
Velocity	4.5 g. at target
References	Report by Dr. Zwicky.

Remarks: Thirty-five projectiles were test flown. For general dimensions see figures 8 and 9. There was a considerable amount of development work still to be done, which will account for the varying fuel rates and efficiencies as outlined in other reports. Above data give average characteristics as developed from static and flight test work. It is interesting to note that the addition of swinging or flexible feed pipes in the tanks produced increased range of 2½ miles. Since this unit was being developed with the idea of filling the tanks and storing for long periods, over-sized tanks were used.



WASSERFALL POWER PLANT

FIGURE 8



WASSERFALL CHAMBER
AND NOZZLE

FIGURE 9

ROCKET POWER PLANT FOR ENZIAN

E-1, E-2, and E-3 RI 210-B

Company	HWK
Location	Kiel
Use	Flak rocket
Design	Vehicle designed by Messerschmitt; manufactured by Holzbau-Kiesing.
Thrust	4400 lbs, dropping to 2000 lbs.
Time	70 sec.
Propellant Rate	28.6 lbs/sec. full thrust
Oxidizer	Mixed acid - 990 lbs.
Fuel	gasoline 242 lbs.
Jet Velocity	5000 ft/sec.
Bottle Pressure	Cast iron pumps operated with HWK steam pot using T-stoff and solid catalyst.
Tank Pressure	600 lbs/sq. in. at full thrust
Chamber Pressure	400 lbs/sq. in.
Dry Weight	80 kg. experimental model
Specific Impulse	156
Total Impulse	308,000 lbs. sec.
Velocity	Mach No. 0.8-0.9
References:	Interrogation, Dr. Wurster and U.S. Naval Technical Report No. 184-45, HWK report.

210-B (cont'd)

Remarks: About ten units were manufactured. Ignition was accomplished by injecting furfuryl alcohol into combustion chamber since it is spontaneous with nitric acid. Rupture discs keep liquids from pumps until piston actuated sleeve cuts discs. This piston is driven into diaphragm with powder charge set off electrically. Fall off of thrust accomplished by allowing feed pressure to drop as the air bottle became exhausted, thereby reducing supply of T-stoff to the pumps.

ENZIAN E-4, E-5

Company	DVK, Dr. Conrad
Location	Berlin
Use	Flak rocket
Design	Messerschmitt - Dr. Wurster
Thurst	(E-4 4400 lbs to 2200 lbs. (E-5 5500 lbs to 3300 lbs.
Time	(E-4 70 sec. (E-5 56 sec.
Propellant Rate	(E-4 24.4 lbs/sec. (E-5 30 lbs/sec.
Oxidizer	Salbei
Fuel	Visol
Jet Velocity	5800 ft/sec.
Bottle Pressure	3000 lbs/sq. in.
Tank Pressure	400 lbs/sq. inch.
Chamber Pressure	300 lbs/sq. inch
Dry Weight	213 lbs
Specific Impulse	181
Total Impulse	308,000 (16 sec approx)
Velocity	(E-4 Mach No. 0.9 (E-5 Mach No. 2.0
References	Dr. Wurster of Messerschmitt

Remarks: Very simple regulation system used. When the motor was started by firing an electric squib, which burst a frangible disc in the pressure tank, the feed pressure was controlled by the drop across a small orifice in the bottle pressure line. The adiabatic expansion of the compressed air was about right for proper thrust control. An electric squib was also used when firing the combustion chamber to prevent hard starts. (see figure 10).

RHEINTOCHTER III

Company	DVK - Dr. Conrad
Location	Berlin
Use	Flak rocket
Design	Rheinmetall-Borsig
Thrust	3960 lbs. to 4800 lbs. for 5 sec; balance of flight 3960 lbs.
Time	43 sec.
Propellant Rate	22.4 lbs/sec.
Oxidizer	Salbei 739.2 lbs.
Fuel	Visol 193.6 lbs.
Jet Velocity	5800 ft/sec.
Bottle Pressure	3750 lbs/sq. inch; 39.6 lbs.
Tank Pressure	400 lbs/sq. inch
Chamber Pressure	300 lbs/sq. inch
Dry Weight	213 lbs.
Specific Impulse	181
Total Impulse	80,000 lbs. sec.
Velocity	600 ft/sec.
References	Dr. Wurster. RH III Handbook

Remarks: Launching units very heavy. Developed by Rheinmetall-Borsig. About 16000 kg. This power plant used spontaneous fuels but an electric powder squib was necessary to prevent hard starts. (see part (a) in figure 11).

POWER PLANT FOR FEUERLILIE F-55

Company	DVK
Location	Berlin - Dr. Conrad
Use	Flak rocket
Design	LFA by Dr. Braun
Thrust	14,000 lbs.
Time	7 sec.
Propellant Rate	6 lbs/sec.
Oxidizer	Salbei 370 lbs (?)
Fuel	Tonka 93 lbs (?)
Jet Velocity	5400 ft/sec.
Bottle Pressure	Compressed air
Tank Pressure	Not known
Chamber Pressure	300 lbs/sq. in.
Dry Weight	
Specific Impulse	169
Total Impulse	98,000 lbs. sec.
Velocity	

References U.S. Naval Technical Mission in Europe Technical Report No. 194-45.

Remarks: Ignition spontaneous; powder squib bursting starters (see part (b) of figure 11). The early F-25 and F-55 used solid propellant power plants. Only the latest design of F-55 used the liquid propellant motors. Two units were constructed.

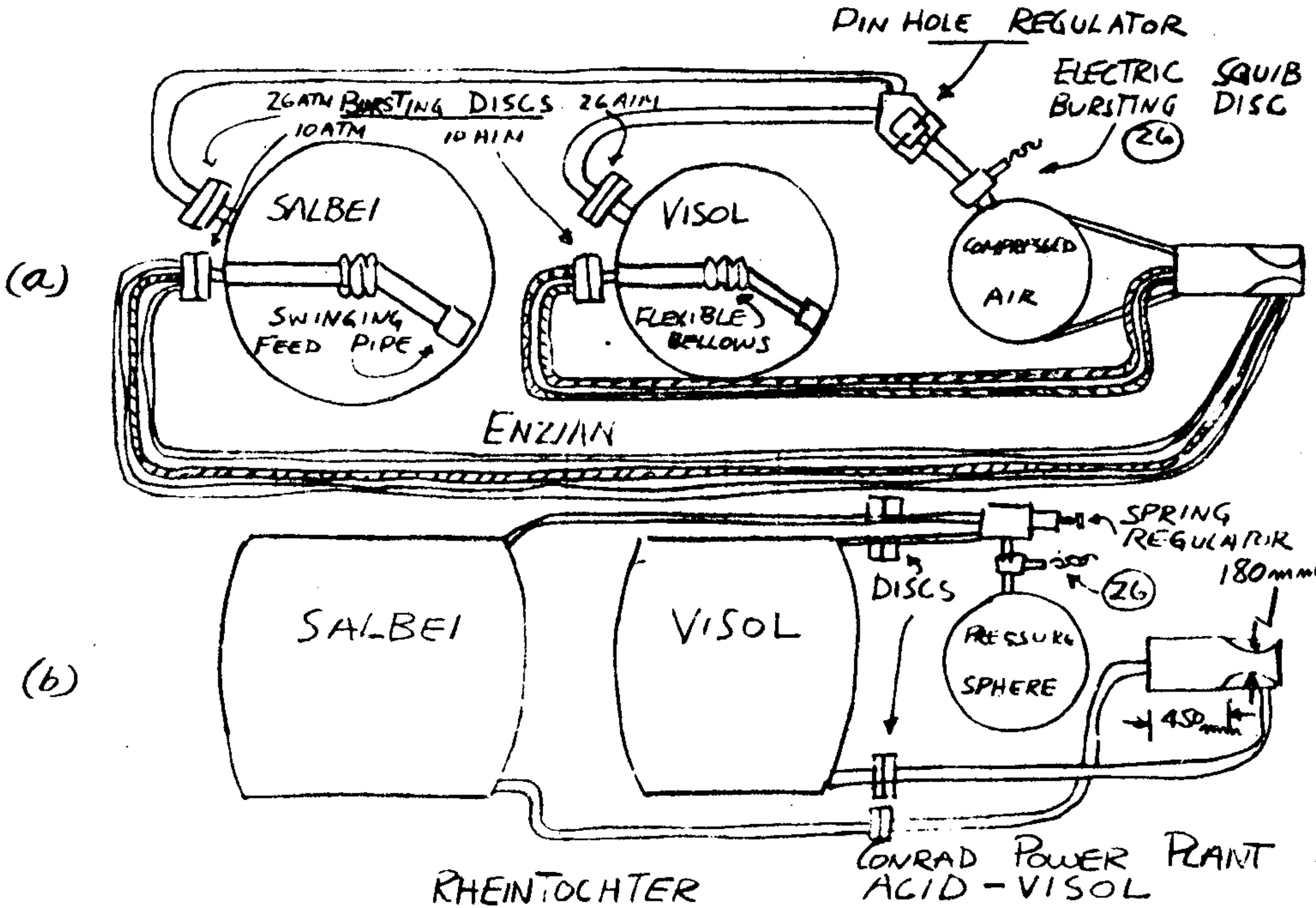

(a)
PIN HOLE REGULATOR
ELECTRIC SQUIB BURSTING DISC
26
26ATM BURSTING DISCS 26ATM
10ATM
10ATM
SALBEI
SWINGING FEED PIPE
VISOL
FLEXIBLE BELLOWS
COMPRESSED AIR
ENZIAN
(b)
SPRING REGULATOR
DISCS
26
180mm
SALBEI
VISOL
PRESSURE SPHERE
450mm
CONRAD POWER PLANT
ACID - VISOL
RHEINTOCHTER
FEUERLILLIE

FIGURE 11

SCHMETTERLING Hs 117

109-558

Company	Bavarian Motor Works (BMW)
Location	Berlin-Munich
Use	Flak rocket and air-to-ground missile
Design	Henschel Flugzeug Werke - Dr. Wagner
Thrust	132 lbs. to 836 lbs.
Time	57 sec. full thrust - 33 sec.
Propellant Rate	4.8 lbs/sec
Oxidizer	Salbei 130 lbs. Sv-Stoff
Fuel	Tonka 28 lbs.
Jet Velocity	5600 ft/sec.
Bottle Pressure	3000 lbs/sq. inch (compressed air)
Tank Pressure	400 lbs/sq. inch
Chamber Pressure	300 lbs/sq. inch
Dry weight	176 lbs. with tanks
Specific Impulse	175
Total Impulse	27,588 lbs. sec. full thrust

Velocity Held to Mach 0.73 by controlling thrust with a ram pressure and altitude regulator

References Dr. Clapp's CIOS report.

Remarks: Spontaneous ignition. Electric powder bursting diaphragm for starting feed.

SCHMETTERLING Hs 117

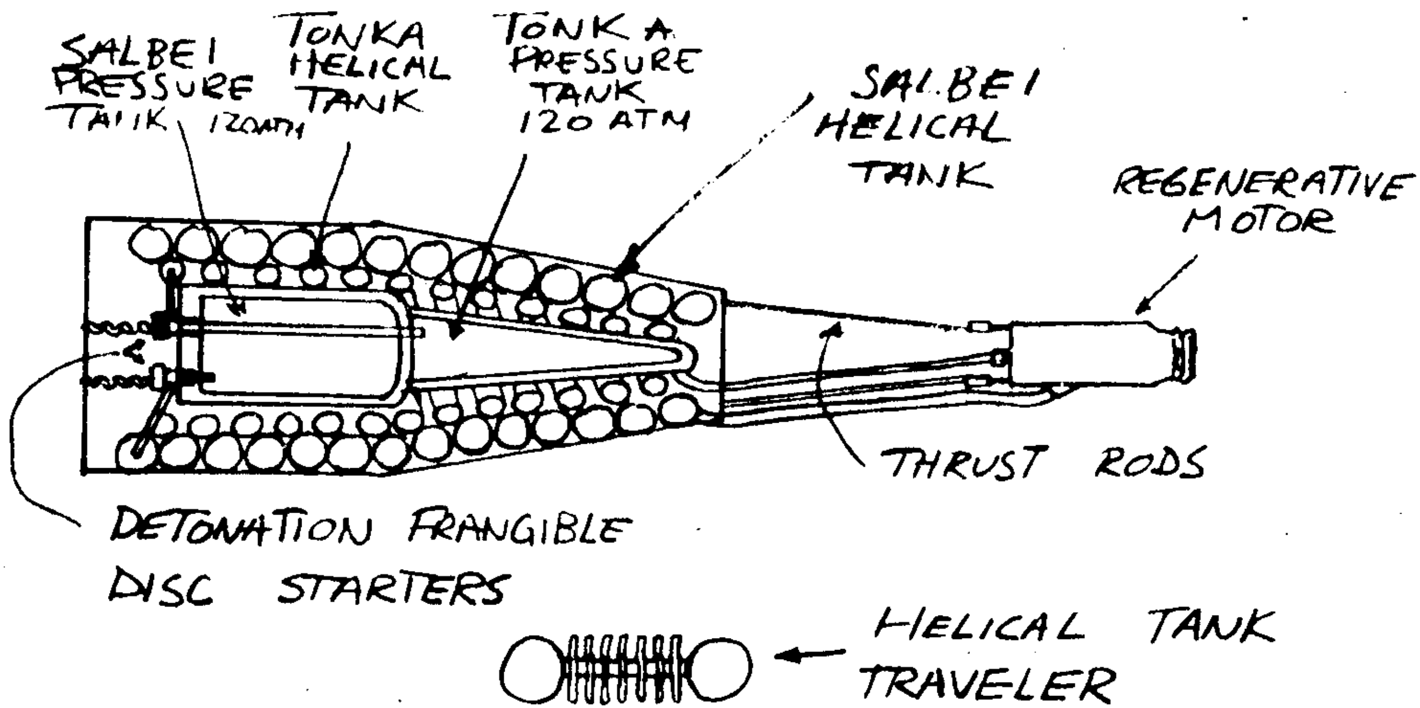
Company	HWK
Location	Kiel
Use	Air-to-ground flying missile
Design	Henschel Flugzeug Werke
Thrust	132 lbs. to 836 lbs.
Time	60 sec; full thrust - 33 sec.
Propellant Rate	5.4 lbs/sec.
Oxidizer	Sv-Stoff 149.6 lbs.
Fuel	gasoline 28.8 lbs.
Jet Velocity	5000 ft/sec.
Bottle Pressure	2700 lbs/sq. inch - 10.45 lbs of gas
Tank Pressure	600 lbs/sq. inch
Chamber Pressure	400 lbs/sq. inch
Dry Weight	143 lbs.
Specific Impulse	156
Total Impulse	50,160 lbs. sec. at full thrust
Velocity regulator.	Held to 0.73 Mach No. with air ram
References	X

Remarks: Tested and ready for production but none were used in combat. Furfuryl alcohol is used for ignition. Approximately 275 lbs. used. Mix ratio 5.8 to 1. Starting is accomplished through medium of electric powder squib which forces round edge piston to break aluminum membrance (Figure 4).

X-4
109-548

Company	BMW
Location	Dr. Schneider - Berlin and Allach
Use	Air-to-air missile
Design	Ruhrstahl A.G. - Dr. Kramer
Thurst	308 lbs. down to 66 lbs.
Time	22 sec; actual - 17 sec. (running time questionable)
Propellant Rate	1.95 lbs/sec.
Oxidizer	Salbei 14.08 lbs.
Fuel	Tonka - 3.52 lbs.
Jet Velocity	5000 ft/sec.
Bottle Pressure	2700 lbs/sq. inch
Tank Pressure	varies as bottle pressure reduces
Chamber Pressure	400 lbs/sq. inch
Dry Weight	31 lbs.
Specific Impulse	156
Total Impulse	1400 lbs. sec.
Velocity	760 ft/sec.
References	CIOS report - Dr. Clapp; British report.

Remarks: 1300 units were manufactured. (Figure 12). The plungers for the helical tanks used chromate leather packing for the tonka and lapolene washer with the salbei. This unit was considered to be very practical for defense against Flying Fortresses.



X-4 POWER PLANT
BMW.

FIGURE 12

Hs SERIES - - 293, -293A-1, -293D, - 294, etc.

(Motor 109-507B, (RII-260)

Company	HWK
Location	Kiel
Use	Ferngesteurte Gleitbombe
Design	Dr. Wagner of Henschel Flugzeuge Werke
Thrust	1320 lbs.
Time	10 sec.
Propellant Rate	12.2 lbs/sec.
Oxidizer	T-stoff 132 lbs. approx.
Fuel	Z-stoff 7.48 lbs.
Jet Velocity	3500 ft/sec.
Bottle Pressure	
Tank Pressure	
Chamber Pressure	270 lbs/sq. inch
Dry Weight	158.4 lbs.
Specific Impulse	109
Total Impulse	13,200 lbs. sec.
Velocity	

References U.S. Naval Technical Mission in Europe Technical Report No. 134-45

Remarks: 300 manufactured. This was known as the cold motor system since the thrust was dependent entirely upon the reaction of hydrogen peroxide releasing about 60% water in form of steam at 500° C plus 40% oxygen gas. Solid propellant units and gaseous oxygen methanol motors were also used in this series.

HS SERIES - Hs 293, -298

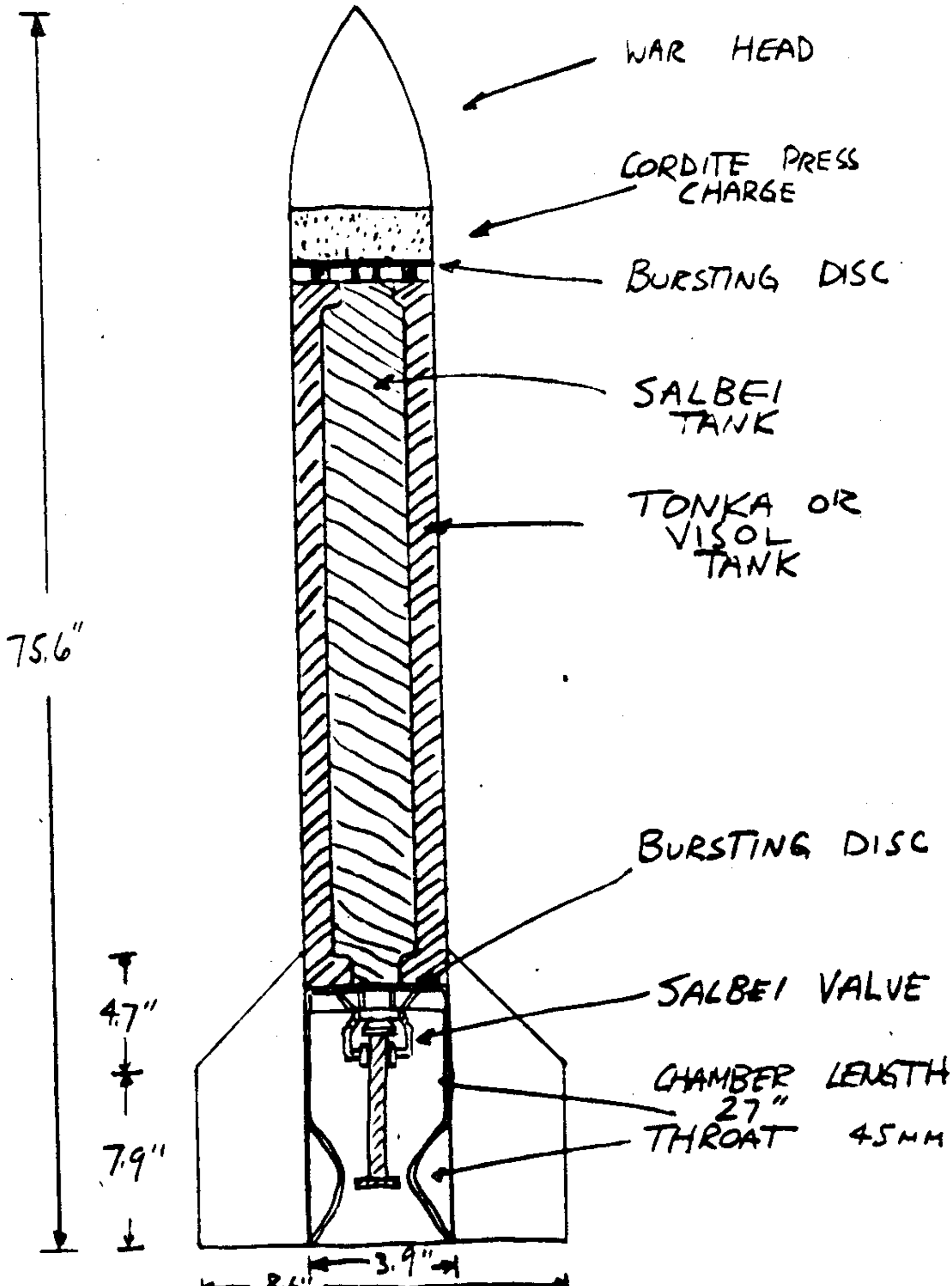
Motors 109-513 and 109-543

Company	Wilhelm Schmidding
Location	Bodenbach
Use	Glide bomb
Design	Henschel Co.
Thrust	513 - Liquid 1474 lbs; 543 - solid 330 lbs at 5 sec. 110 lbs at 30 sec.
Time	513 11 sec.
Propellant Rate	513 - 8.49 lbs/sec; 543 - 2.8 lbs/sec.
Oxidizer	513 - oxygen gas; 543 - solid propellant
Fuel	513 - M-stoff; 543 - propellant deglycol.
Jet Velocity	513 - 5600 ft/sec; 543 - 5100 ft/sec.
Bottle Pressure	Oxygen bottle pressure - 3300 lbs/sq. in.
Tank Pressure	X
Chamber Pressure	X
Dry Weight	X
Specific Impulse	513 - 175; 543 - 160
Total Impulse	513 - 16,214 lbs. sec; 543 - 11,220 lbs. sec.
Velocity	X
Reference	Henschel microfilm· Schmidding Documents.

Remarks: Both of these units were developed by Wilhelm Schmidding. The primary function of these power plants, as with HWK units, is to give the missile initial impulse so that pilot can see to control it from airplane.

Company	Electromechanische werke
Location	Peenemunde
Use	Anti-aircraft barrage
Design	Peenemunde
Thrust	1320 to 2200 lbs.
Time	2-3 sec.
Propellant Rate	9.6 lbs/sec.
Oxidizer	Salbei - tank capacity 15.9 lbs.
Fuel	visol - tank capacity 5.73 lbs.
Jet Velocity	3200 ft/sec.
Bottle Pressure	735 lb/sq. inch generated with cordite charge.
Tank Pressure	charge ruptures discs at 37-74 lbs/sq. inch.
Chamber Pressure	about 440 lbs/sq. inch
Dry Weight	42.63 lbs.
Specific Impulse	100
Total Impulse	2200 lbs. sec. to 3000 lbs sec.
Velocity	starts at 31g; at target about 45 g.
Reference	British CIOS report - U S Army report

Remarks: It will be noted that the efficiency appears quite low and that there is a wide range of characteristic data. The projectile was still experimental and it is believed that the specific fuel consumption had not been determined accurately. Also the L/D of chamber was poor because of their desire to increase tank capacity. N_2 was used in static tests. It was to be shot from launcher. When fired, visol came on full, with Salbei being delayed until Valve 1 was caused to open by gases passing venturi throat (Figure 13). Altitude from 46,000 ft. to 52,000 ft.



TAIFUN

FIGURE 13.

A-1, A-2

PRELIMINARY DESIGN FOR V-2

Company	Dr. Oberth - Prof. Von Braun
Location	Berlin Rocket Flying Field
Use	experimental rocket flights
Design	1933-1934
Thrust	660 lbs.
Time	16 sec.
Propellant Rate	5.5. lbs/sec
Oxidizer	A-Stoff
	Total propellants 88 lbs.
Fuel	M-Stoff plus water
Jet Velocity	about 4000 ft/sec.
Bottle Pressure	N_2 feed used
Tank Pressure	X
Chamber Pressure	X
Dry Weight	242 lbs. rocket and motor
Specific Impulse	125
Total Impulse	10,560 lb. sec.
Velocity	
Reference	

Remarks: Length about 1.4 meters; diameter 30 cm. Gyro-stabilized; range 2000 meters or 1.2 miles.

A-3, A-5, and A-7

PRELIMINARY A-4 DESIGN

Company	Army Weapon Department
Location	Army Weapon Department
Use	Experimental flight tests 1938
Design	Berlin - Dr. Von Braun
Thrust	3300 lbs.
Time	45 sec.
Propellant Rate	22 lbs/sec.
Oxidizer	A-stoff
Fuel	M-stoff plus water (Total propellant: 990 lbs.)
Jot Velocity	4600 ft.
Bottle Pressure	nitrogen
Tank Pressure	X
Chamber Pressure	X
Dry Weight	660 lbs. rocket and motor
Specific Impulse	145
Total Impulse	148,500 lb. sec.
Velocity	Did not attain supersonic speeds
References	

Remarks: Maximum range 1200 meters for A-3; A-5 made with graphite rudders and could be landed with chute; maximum slant range 10.8 miles for A-5; A-7 preliminary A-9 design with wings was not built.

A-4 or V-2 ROCKET

A-9 1945 DESIGN

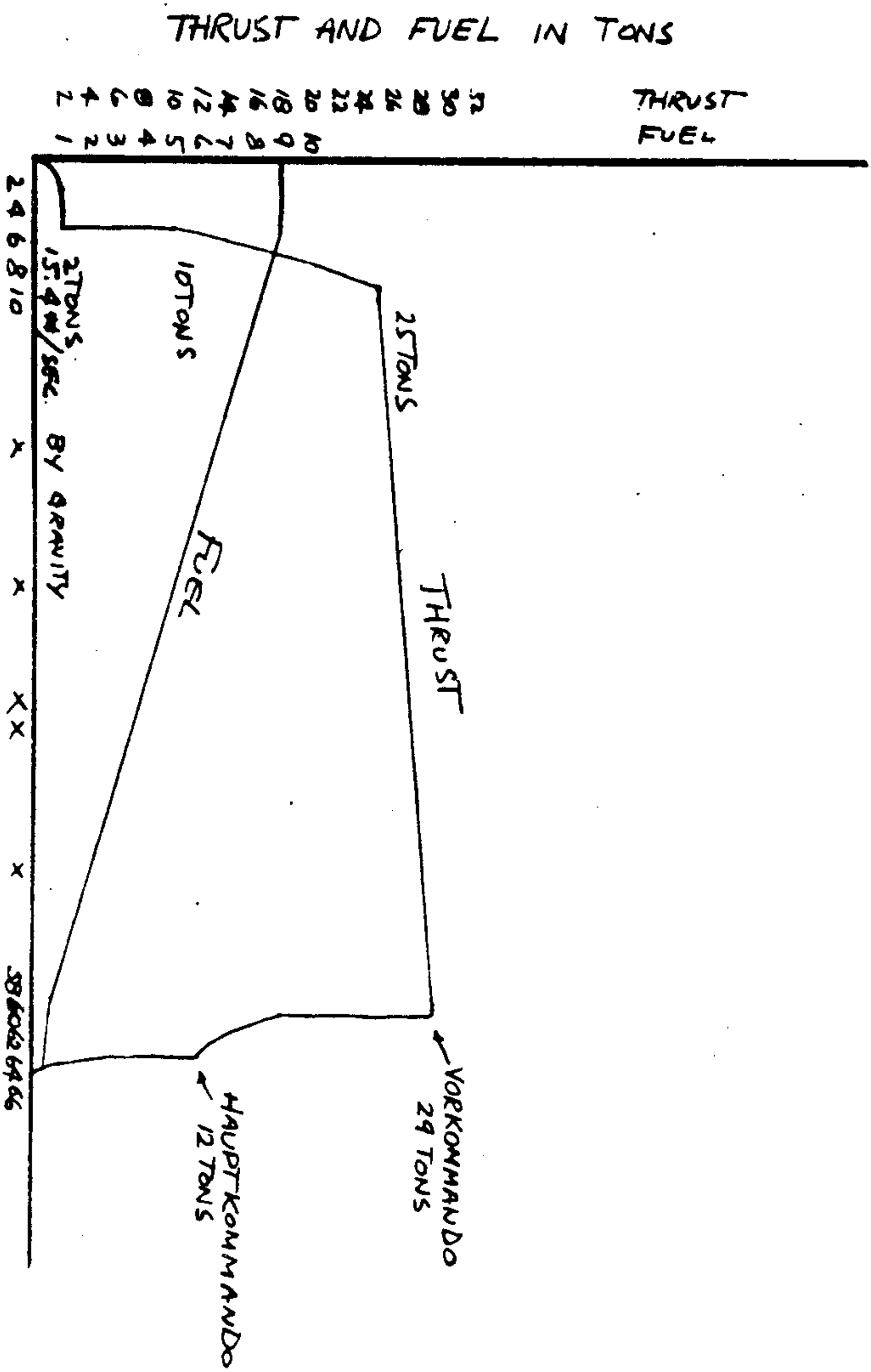
Company	Peenemunde
Location	Peenemunde
Use	Artillery Rocket
Design	EMW in 1940-1942
Thrust	55,000 lbs.
Time	68 sec. max.
Propellant Rate	280 lbs/sec; Total Propellant 17,600 lbs; (actual? 18,209.4 lbs)
Oxidizer	Liquid oxygen 9856 lbs; Mix ratio - 1 to .85
Fuel	Methanol 8353.4 at (75% M-stoff and 25% water)
Jet Velocity	6350 ft/sec.
Bottle Pressure	3000 lb N_2 for Pump T-stoff feed (regulated to 495 lbs/sq. inch ± 0.6 atm)
Tank Pressure	Pump delivery pressure 375 lbs/sq. inch.
Chamber Pressure	300 lbs/sq. inch
Dry Weight	9900 lbs. of rocket and motor
Specific Impulse	200
Total Impulse	3,740,000 lbs. sec.
Velocity	about 4g max.
References	Army Peenemunde Report

Remarks: (a) Pump turbine developed 540 HP at 4000 RPM with a fuel consumption of 5.5 lbs/sec. Pumps were actually run between 3600 and 3800 RPM. Because of water hammer difficulties when shutting down, the cycle consisted of two steps (Figure 14).

(b) Combustion chamber used 18 injector cups with an atomization pressure of 45 lbs/sq. inch. Drop through jacket 75 lbs/sq. inch. A specific impulse of 220 was attained in test bed operation, but due to increase of 18% thrust and chamber pressure at high altitudes it was found necessary to run at reduced efficiency. As a compromise, the nozzle was designed for an exhaust pressure of 12.75 lbs/sq. inch obsolute.

(c) It is to be noted that the ring of 36 liquid cooling jets in the combustion chamber were filled with woods metal and did not spray until chamber temperature became high enou h to melt the plugs at about 50o C.

(d) The A-9 rocket would have used the same power plant as A-4, but was to be equipped with wings. Range increased to about 450 miles. One variation was to have had a retractable undercarriage, carry a one man crew in a pressure cabin, and would land empty at about 150 miles per hour.



TIME IN SECONDS

A-4 PROGRAM GRAPH

FIGURE 14

A-10

PROJECTED LONG RANGE ARTILLERY ROCKET

Company	Peenemunde
Location	Peenemunde
Use	Booster or step rocket
Design	EMW
Thrust	440,000 lbs.
Time	50 sec.
Propellant Rate	2728 lbs/sec
Oxidizer	A-stoff Total Propellant weight: 136,400 lbs
Fuel	M-stoff plus water
Jet Velocity	5300 ft/sec.
Bottle Pressure	N2
Tank Pressure	X
Chamber Pressure	X
Dry Weight	55,000 lbs. rocket plus motor plus step A-9.
Specific Impulse	166
Total Impulse	11,000 ton sec.
Velocity	Jettisons at 3800 ft/sec.
References	

Remarks Similar to A-9 but with step rocket. Accelerates to about 7000 ft/sec. and then goes into glide. Maximum range 3000 miles.

BV-143
(Similar to RI-203/209)

Company	HWK
Location	Kiel
Use	Glide Bomb
Design	Blohn & Voss - Hamburg. Dr. Vogt
Thrust	3300 lbs. reducing to 1540 lbs.
Time	40 sec. approx: 30 sec. full thrust
Propellant Rate	19.8 lbs/sec. at full thrust
Oxidizer	T-stoff Total Propellant Weight: 594 lbs.
Fuel	Z-stoff plus B-stoff and gasoline
Jet Velocity	5000 ft/sec.
Bottle Pressure	Air Pressure
Tank Pressure	X
Chamber Pressure	300 lb/sq. inch
Dry Weight	176 lbs. - charged weight: 770 lbs.
Specific Impulse	156
Total Impulse	96,000 lbs. sec.
Velocity	X
References	

Remarks: Only four units built; project dropped in 1943. Starting method - powder squib ruptures disc.

6. MISCELLANEOUS JET POWER PLANT SYSTEMS

The following sheets list the operating characteristics of jet power plants or devices that do not come under any of the previously mentioned items. The LT 1200 and 1500 were rocket propelled underwater torpedoes and were entirely designed and built by HWK for T-Stoff propellants.

Under the guidance of Dr. Lippisch, DFS at Ainring developed and wind-tunnel tested a high speed flying wing interceptor model using a coal-type ramjet. The design was changed from cylindrical to oval in order to facilitate ints installation in the wing. No loss of efficiency was noted; however, a rotating fuel holder was necessary to maintain even combustion of fuel layers.

Some development work was done by Baron Dohlhoff on a sort of thermal air type of jet propelled helicopter. A series of four ships were built, NR-1 to 4, NR-1 was built in 1943 and used a 60 HP blower, NR-2 used 90 HP for the blower. NR-3 and 4 had a total of 135 HP and used about 35 gallons of fuel per hour when hovering. The fuel was injected into the blower air stream at 5 atm pressure, the total mixture traveling out through the hollow blades to the combustion chamber on the blade tips before burning.

Some information is included on improved impulse duct motors similar to the V-1 motor, see figure 15.

LT 1200 and LT 1500

Company	HWK
Location	Kiel
Use	Rocket propelled water torpedo
Design	HWK
Thrust	1760 lbs.
Time	106 sec.
Propellant Rate	11.7 lbs/sec.
Oxidizer	T-stoff 832 lbs
Fuel	Gasoline - 103.4 lbs; z-stoff - 62 lbs.
Jet Velocity	6050 ft/sec.
Bottle Pressure	3000 lbs/sq. inch
Tank Pressure	435 lbs/sq. inch
Chamber Pressure	285 lbs/sq. inch.
Dry Weight	1800 complete torpedo
Specific Impulse	189
Total Impulse	186,560 lbs. sec.
Velocity	X

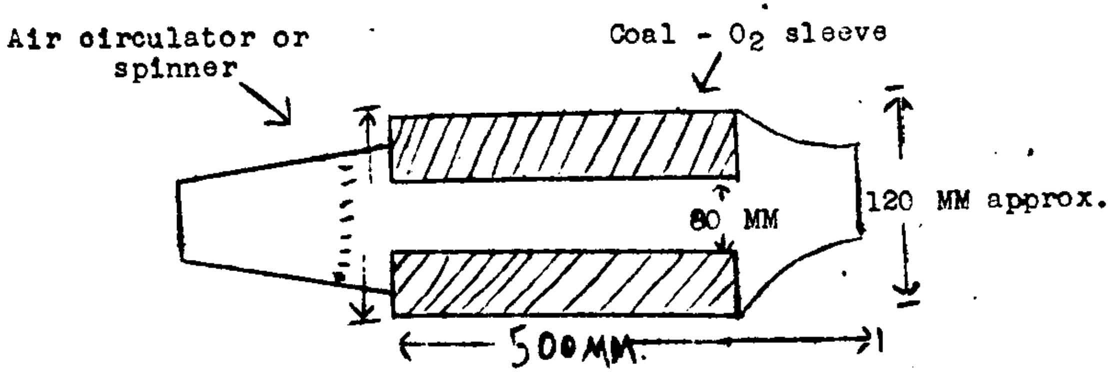
References U.S. Naval Technical Mission in Europe Technical Report No. 134-45.

Remarks: Theoretical temperature 2000°C; combustion chamber cooled with sea water. Mechanical trigger valve used for starting.

RAM JET

Company	DFS - Propellant - Dynamit A.G.
Location	Ainring
Use	Preliminary design for Lippisch P-13B jet plane.
Design	Dr. Lippisch - Dr. Saenger
Thrust	
Time	
Propellant Rate	
Oxidizer	90% coal; 10% black powder
Fuel	formed into a sleeve
Jet Velocity	
Bottle Pressure	
Tank Pressure	
Chamber Pressure	
Dry Weight	
Specific Impulse	Thrust coefficient - .3
Total Impulse	
Velocity	Must stay above 180 MPH at 260 MPH 7% efficient
References	Dr. Lippisch

Remarks:



POWER PLANT FOR JET HELICOPTER

Company	Doblhoff - Argus 411 engine
Location	Zell am see
Use	Jet Helicopter
Design	Doblhoff
Thrust	
Time	
Propellant Rate	Single stage centrifugal blower driven with argus 411 - 135 BHP motor 1.44 lbs. air/sec at 28.5 lbs/sq. inch.
Oxidizer	
Fuel	Gasoline injected at mix ratio of 1 to 20.
Jet Velocity	
Bottle Pressure	
Tank Pressure	Fuel injection pressure 60 lbs/sq. in
Chamber Pressure	
Dry Weight	Helicopter and motor - 946 lbs.
Specific impulse	
Total Impulse	
Velocity	Blade tip speed or take off speed 283 RPM.
References	Tech. Intelligence Report I-56.

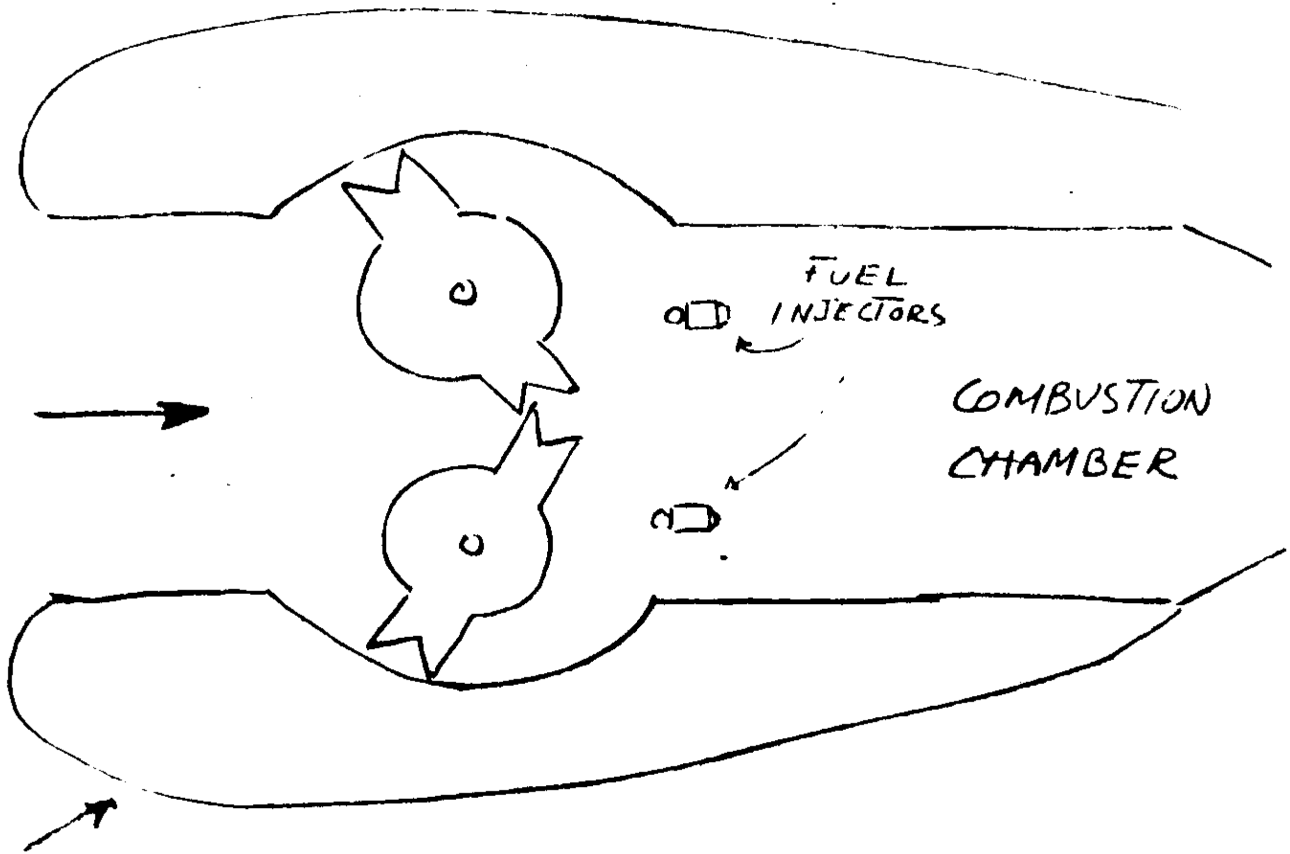
Remarks: Air compressor drives compressed air to hub and out hollow blades to combustion chamber on tips. Fuel is injected before entering hub. 4 models built - NR-1 to -4. NR-4 - a two place unit had 25 hours hovering time, little or not forward flight. Fuel consumption: 140 liters/hr for hovering, and 40 liters/hr for forward flight.

V-1-A, -B, -C -D and -E

SCHMIDT-ARGUS REED MOTOR

Company	Argus Motoren Werke
Location	Berlin/Reinikendorf
Use	Power Plant for flying bomb V-1
Design	Schmidt - Final development by Argus
Thrust	500 lbs. to 700 lbs. about 700 HP at 400 miles/hr
Time	About 30 minutes for life of valve
Propellant Rate	35 to 5 lb/hour/lbs. thrust
Oxidizer	Ram air
Fuel	Benzin-low grade gasoline
Jet Velocity	800-900 ft/sec. (theoretical)
Bottle Pressure	
Tank Pressure	
Chamber Pressure	
Dry Weight	300 lbs. - 350 lbs.
Specific Impulse	
Total Impulse	
Velocity	400 miles/hr.
References	Das Schmidt Rohr

Remarks: Shaefert at Ainring worked on the improvement of Schmidt Rohr valve. The inlet area was improved by removing some of the cross bars in the grid frames. Prevented nibbling and chipping by allowing the reeds to close on one another. They increased efficiency by lengthening the duct and improving the streamlining of inlet housing. 80% increase in efficiency. To investigate valve timing (Figure 15) they used a double rotor valve with teeth for positive cutoff on closing. Efficiency was increased about 40%. N2O was tested by Bussing by mixing it with gasoline giving an increased thrust of 15% to 20%. However, this was a very preliminary investigation and very little data had been collected before the close of the conflict.



PULSE MOTOR VALVE FOR
POSITIVE CUT OFF

FIGURE 15

V

7. CONCLUSIONS

(a) German rocket motor development is in advance of the American program by at least four years in relation practice, application, and magnitude both of the power plant size and the scale of production. There are numerous novel features in the feed systems and methods of control. It is to be noted, however, that the motor operating efficiencies are not exceptional, and it is believed that in certain phases of development, U.S. power plants are superior. In a large measure it is superiority has been because of a greater supply of critical materials in the United States.

(b) The German rocket fuel program was very extensive and many fuel systems were investigated. The most outstanding fuel system was the one that used hydrogen peroxide. However, it must be considered with much reserve because of the explosive nature of H2O2. For this reason certain research groups in Germany preferred the nitric acid system, although the acid was somewhat more difficult to handle logistically.

(c) Liquid propellant JATO devices were generally discontinued except in cases where long running time was desired.

(d) Solid propellant units were coming into use in their stead, because they involved a simpler handling problem.

(e) Very little work had been done recently with liquid oxygen systems as aircraft prime movers. The source of supply of liquid oxygen was available only fo the V-2 program and had not been solved satisfactorily.

(f) All test flights on the Me 163 were made with H2O2 motors although an acid motor had been developed for the purpose.

CONCLUSIONS (cont'd)

(g) The difficulties with cavitation, leakage and H_2O_2 explosions in flight had not been corrected entirely at the end of the war, although a great amount of development work was being done in this connection.

(h) In the early stages of development the missile power plants consisted of liquid propellant JATO units which were used for the preliminary experimental flights. Having gained the necessary information, many motor units were designed and built for individual application, the trend being toward the simplest of systems and fuels.

(i) The acid-hydrocarbon fuel system was considered the most desirable because of the availability of the nitric acid. Used with the simplest of control valves, such as frangible bursting diaphragms in the propellant lines, this motor unit was the least expensive to manufacture and was reliable enough for the purpose intended.

(j) An important feature of the acid system was that it could be charged with fuel and stored for long periods, thereby improving the supply and handling situation.

(k) It appears that the general trend was toward solid propellant units for small rocket missiles and JATO units, liquid units being designed for high thrust with long duration.

(l) Development work was being carried on to increase efficiency and running time of the V-1 resonant duct engine. An increased thrust of 20% was effected by injecting an oxygen carrier into the fuel system. This development however was in an extremely preliminary stage and little data had been accumulated.

(m) Ramjets or athodyds were investigated by HWK, Saenger at LFA and DFS, Lippisch in Vienna, Pabst at Focke-Wulff, and Oswatitsch of KWI- Goettingen. The Pabst unit was a very important development. Ramjet work at Walter Works had made great strides also. Very few of the ramjet power plants had been flight tested and none had been used operationally.

(n) A jet helicopter using the Doblhoff air blower system was test flown successfully.

8. RECOMMENDATIONS

(a) It is recommended that certain of the Visol and Tonka fuels be tested, for use in the U.S. missile program as a possible solution to the viscosity-temperature problem.

(b) Dr. Schmidt of the HWK and/or some of his staff might well be brought to the United States to assist in the further development of aircraft rocket plants.

(c) Improvements and test stand runs be made on the Me-163 power plants before flight testing.

(d) Such features as the powder squib pressuring valves, and frangible disc propellant valves used in the German missile power plants be incorporated in the present missile power plants in process in the U.S.

(e) A development program be established for further investigation of the HWK injector throttling method, ejector pumps, and motor jacket relief valves, for use in other plant systems now underway in the U.S.

(f) Some study be made concerning the Lippisch coal burning ramjet for application to controlled missiles.

9. <u>REFERENCES</u>

(a) HWK Operation Handbooks - 109-509A-1, C-1

(b) U.S. Naval Technical Mission in Europe Technical Report No. 134-45.

(c) CIOS Report of Dr. Clapp.

(d) Army Peenemunde Report - Investigator Dr. Zwicky.

(e) Army Nordhausen Report.

(f) Das Schmidtrohr - Paul Schmidt.

(g) HWK System - microfilm.

(h) Schmidding documents.

(i) Technical Intelligence Reports I-56, I-51, I-52, I-53, I-46.

(j) LFA Fuels report - Dr. Lutz - Dr. Noeggerath 26.3 - 1.4.43.

(k) Microfilm Peenemunde Group - collected by Dr. Zwicky.

It is important that these documents and reports be made available to all power plant groups in the United States as soon as they are available.

Prepared by:

LOWELL LAWRENCE
USN Technician.

APPENDIX "A"

MICROFILM PERTAINING TO ROCKETS AND GUIDED MISSILES

REEL NUMBER	DATE SENT TO US NAVY	TITLE
SP. 2A	23 July 1945	Flight tests on the Heimstschutzer II, a Me 262 Aircraft with Two (2) He S-011 installations and Two (2) Walter Rocket Installations - Performance Charts.
"	" " "	Comparison Calculation charts on the Me 262A Heimstschutzer II with Two (2) He S-011 and Two (2) Walter Rocket Installations and the Me-163 C.
157	17 July 1945	Testing Instructions for launching gear for V-I for possible Naval Use. 1945
82	30 June 1945	Two (2) copies of temporary operating instrcutions of the R-109-718 Rocket installations used in conjunction with the JUMO 109-003R Jet Engine.
82	" " "	Instructions and safety rules when refueling with "SALBEI" (S-Stoff) and "TONKE" (R-Stoff) Rocket Fuel Material.
"	" " "	Brief description of the Heimstschutzer I as used in conjunction with Me-262 having JUMO Jet engines and the Walter Rocket Installations.

APPENDIX "A" (cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
82	30 June 1945	Brief description of the Heimatschutzer II as used in conjunction with Me-262 having BMW jet engine Plus rocket installations.
77	2 July 1945	Two copies of 18 blue prints of a 109-718 rocket assembly.
"	" "	Two copies of 7 blue-prints of a 109-558 rocket assembly.
"	" "	BMW board meeting from 6 February 1945 to 9 March 1945 regarding production planning and changes in Rocket activities; Report on.
"	" "	General description including performance data on the combination BMW 109-003R (Jet Type Engine) with a 109-718 rocket assembly for increased take-off and climb performance on heavily armed fast fighter type aircraft.
146	30 June 1945	Miscellaneous research reports from E'stelle Rechlin Peenemunde Division on the HS 293, and 294, Fritz X and other guided missiles. 1942-1943.

APPENDIX "A" (cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
146	30 June 1945	Miscellaneous research reports and correspondence Pertaining to Frits X HS 293 DV 143 and other directed missiles, from Peenemunde. 1941-1942
"	" " "	Two booklets with drawings by the Rhinemettal-Borsig factory containing descriptions, pictures and plans on the first design dated April 1943 and description, pictures and plans of the second design of the Rheintochter I and III - directed anti-aircraft on REEL 147.
147	30 June 1945	Miscellaneous research reports, pictures and correspondence on HS 293 and 294 and other guided missiles including actual reports of operational employment of these weapons. 1944.
"	" " "	Miscellaneous research reports, pictures and correspondence of the HS 290, 298 and other direct missiles. One report of a study of defense against V-I's, reports on the operational employment of directed missiles, teletypes to research center at Karlshagen pertaining to the X-4 and HS 293, and other assorted documents on guided missiles and secret weapons.

APPENDIX "A" (cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
148	30 June 1945	Correspondence between RLM ?(PLM? and Rheinmetal-Borsig concerning the Rheintochter project. 1944
"	" " "	Miscellaneous reports with photographs and drawings on the development and research status on the Rheintochter I and III comprising data, on various parts and accerious during the end of 1943 and 1944.
"	" " "	A set of basic drawings of theRheintochter III 1944.
"	" " "	Miscellaneous correspondence dealing with research on the control mechanism of the Rheintochter. 1944.
"	" " "	Report on steering experiments and various speed measurements of models of theRheintochter. 1944.
"	" " "	Description of liquid fuel driven directed anti-aircraft rockets, (Rheintochter III). 1944
149	" " "	Correspondence with pictures and blue-prints of the electrical c ntrol equipment for the Rheintochter. 1944.

APPENDIX "A" (cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
150	30 June 1945	Several folders of details with pictures and drawings on various tests and experiments of the Rheintochter III and II during 1943, and 1944.
152	30 June 1945	Miscellaneous correspondence between Rheinmetall and sub-contractors pertaining to production and experiments on the Rheintochter. 1944.
"	" " "	Miscellaneous test reports on electrical and radio control equipment of the Rheintochter. 1943.
"	" " "	Miscellaneous correspondence, blue-prints and lists concerning experimental research of the Rheintochter including a list of code names for the Rheintochter project.
153	" " "	Installation instructions with pictures and parts lists 109-509 A Walter Rockets. One report entitled C-Stoff pertaining to the physical and chemical peculiarities of the fuel for the Walter Rocket. 1944
139	" " "	Five files from Herr Leidreiter PLM representative RLM? at Mittelwerk pertaining to application for miscellaneous changes in the construction of the V-2.

APPENDIX "A" (Cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
139	30 June 1945	Five preliminary test reports for the V-2, at various stages of construction, such as electrical pneumatic tests on the motor head and other tests pertaining to the main body of the Rocket.
"	" " "	Twelve folders of assembly plans containing numerical indexes on assembly of rudders fuel containers, various parts of the body, electrical cells and other intricate components of the V-2.
"	" " "	One folder on preliminary instructions on production plans for assembly of the V-2. 1945.
140	" " "	Inspection report submitted on assembly modifications of the V-2. 1944-1945.
"	" " "	Report on failures during launching of various V-2's 1944-1945.
"	" " "	Lists of all V-2 subcontractors and all PLM agencies dealing with V-2 productions. 1943 and 1944.
142	" " "	Blue-prints on various testing apparatus for the Honnef (electrical steering apparatus as used in conjunction with the V-2. 1944.

APPENDIX "A" (cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
142	30 June 1945	Description and testing instructions on the Victoria (steering mechanism for the V-2) 1945.
"	" " "	A folder of despatch lists of completed V-2's to various firing sites up March 30, 1945.
"	" " "	Miscellaneous folder of proposed modifications of various parts of the V-2, 1945.
"	" " "	A folder entitled "Only copy of modification from number 106 to 286 that are to be accomplished on the V-2.
155	" " "	One folder of wind tunnel experiments from Air Research institude Graf Pertaining to a Rocket entitled "Drache".
128	29 June 1945	Drawing of the front and back and complete sketch with part list for the Taifun Rocket.
136	" " "	Various reports by the Mittelwork Manufacturing Co. on the production condition of the V-2 at various stages from Aug. to Sept. 1944.

APPENDIX "A" (cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
136	29 June 1945	Organization and service instructions for the production inspection section for the V2 at Mittlewark 1944.
137	" " "	Descriptions and pictures of the various parts manufactured and the different V2 construction groups.
"	" " "	Preliminary tests instructions for the original testing of electrical accessories for V2 at Mittelwork.
	" " "	Miscellaneous correspondence and reports on the V2 about various visits and meeting with V2 subcontractors b Herr Leidweiter, PLM representative at Mittelwork.
138	" " "	Miscellaneous correspondence regarding production delivery, launching results and failure reports on the V2. 1944-1945.
"	" " "	Correspondence between Azanic Werke and Mittelwerk on the production, shortages, and failure reports on the rudder machine for the V2. 1944.

APPENDIX "A" (cont'd)

REEL NUMBER	DATE SENT TO US NAVY	TITLE
138	29 June 1945	Reports from the various V2 launching companies on the condition of the V2's upon arrival at the launching cities. Further more reports by the same companies on the behaviour of the V2's during launchings on success or failure thereof.
"	" " "	Miscellaneous correspondence, productions records and testing records from the Voss-Werke Barstedt pertaining to the V2 Tellerboedan (flat bottom) 1943-1944.
116	15 June 1945	Plan of a Jet Engine 109-003 with attached R-Equipment, 1943.
"	" " "	Blueprints of the Rocket Starter Unit of the Me 262, 1943.
		Das Schmidtrohr, LFA report on Fuels (Dr. Noeggrroth Dr. Lutz).