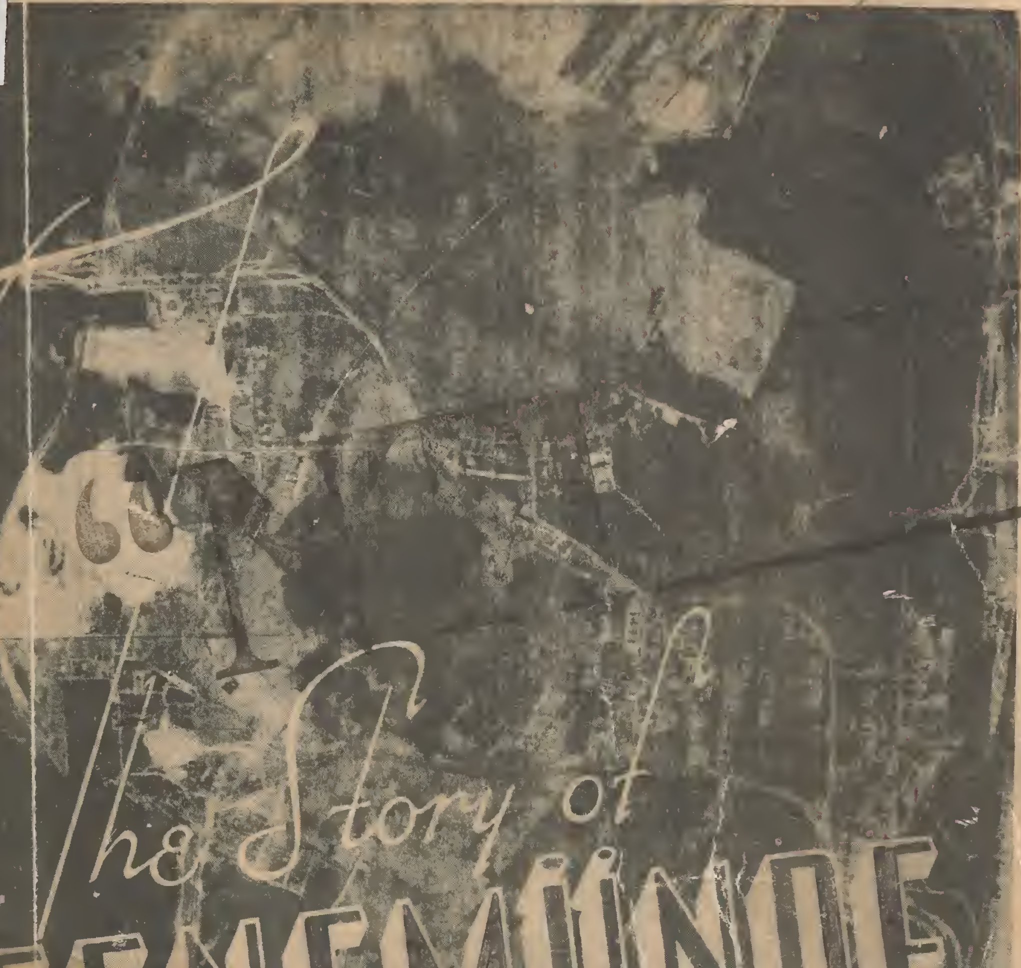
RESTRICTED



The Story of PEENEMÜNDE

or what might have been

RESTRICTED

RESTRICTED

CLASSIFICATION CHANGED
TO RESTRICTED
BY AUTHORITY OF C. G. ATSC
BY J. M. DEBEVOISE, 1ST. LT.
DATE

PEENEMUNDE EAST

Through the eyes of

500

detained at Garmish

This is a Preprint of approximately
one-third of the complete story
of Peenemunde

This printing being accomplished
with the best copy available

RESTRICTED

PEENEMUNDE MANAGEMENT

Represented by Lt. Gen. Dornberger

Index of Photographs of Models
of the Wasserbau, Versuchsanstalt
Kochelsee G.m.b.H.

Photograph 1. From left to right

(1) First provisional model for A5 for testing stability in a travelling truck.

(2) A-5 model for oscillation measurements around various cross axes to ascertain the stability.

(3) A-5 model for three component measurements.

(4) A-5 model with braking flaps for three component measurements at high Mach Nos. (Ma = 2.5 -- 4.4)

(5) A4 model for three component measurements at Mach No 1.2

(6) A4 model for oscillation measurements at wish 2.

(7) A4 model for three component measurements at high Mach Nos.

(8) A4 model without stabilizing unit for three component measurements at Mach No. 1 Z

(9) A4 model without stabilizing unit for three component measurements at medium Mach Nos (Ma = 1.6 -- 2.5)

(10) A4 model without stabilizing unit for three component measurements at high Mach Nos.

Photograph 2. From left to right.

(1) A4b - Trapezium wings shape 4 with biconvex profiles.

(2) Trapezium wings Shape 4 with parallel wings and sharpened front and back edges. (A4b)

(3) A4b - Trapezium wings Shape 5

(4) A4b - Stepped up wings Shape 6

(5) A4b - Stepped up wings Shape 8

(6) A4b - Model with triangular wings shape 14.

Photograph 3. From left to right.

(1) A4 Glider with swept back wings for Ma , 1.2

2) A4 - Glider with swept back wings for medium Mach No.

3) A4 - Glider with swept back wings A4b

4) A4 - Glider with double wings.

5) A4 - Glider with combination of wings and high tail unit.

6) A4 - Glider with stepped up wings.

7) A4 - Glider with stepped up wings with larger span.

Photograph 4

1) The same models as in photograph 3 with aspect below 60°

Photograph 5 "Wasserfall" models from left to right

1. The first shape $\Delta\varphi = 45°$ in which $\Delta\varphi$ means the twisting of the wings (Flugelkreuz) against the tail unit (Leitwerkkreuz) about the longitudinal axis of the model.

2. Model with ring for wings.

3. Final shape $\Delta\varphi = 0°$

4. Model with fixed back wing unit $\Delta\varphi = 45°$

5. Model for oscillation and zero moments measurements to test stability and efficiency of the tail unit.

6. Model for Mach No. 1.2

7. Model with split tail unit.

8. Oscillating half model.

Photograph 6. From left to right.

1. Peenemunde fin stabilized model (PPG) cartridge case base projectile for K5.

2. Peenemunde fin stabilized model
Cartridge projectile model

3) Peenemunde fin stabilized model
Final cartridge base projectile model with guide ring.

4) Peenemunde fin stabilized model
Test of a combined guide and support ring

5) Peenemunde fin stabilized projectile
Final form for cluster projectiles.

6. 3 Pieces per cartridge case base.

7. 5 " " " " "

8. 8 " " " " "

9. 12 " " " " "

10. 33 " " " " "

11. 16 " " in the tube model

<u>Photograph 7</u> From left to right

10.5 / 7.5 cm shells.

1) For Paw 1000 with 8 axis parallel fins
2) " " " " " /\ fixed shortened fins
3) " " " " split tail unit (fins)
4) " " " " 6 /\ fixed fins
5)
6 Mine shells designed by Baake with long tail unit
7) " " " " " " shortened " ") differently put
8) " " " " " " " " ") together.

9) PPG tail unit with 2 fins

10) " " " " 3 fins for cartridge case base

11) " " " " 4 "

12) " " " " 4 " arranged at 5°

13) " " " " 4 /\ arranged fins

14) " " " " 6 /\ " "

15) " " " " 6 fins arranged at 5°

16) Roehling model with folding spring steel tail unit

<u>Photograph 8.</u>

1) Jet model stern with jet rudders.

2) A4 pressure distribution half model

3) "Wasserfall" pressure distribution half model

4) A4b Half model for the measurements charnier moments.

5) Model of "Wasserfall" stern with 8 different rudders (one rudder attached)

Photograph 9.

1) A4 model with adjustable rudders to control roll moments for measurements in the high speed wind tunnel of the DVL at Adlershof.

2) A5 - Pressure distribution model for measurements in the wind tunnel of the TH Aachen.

3) A4 jet model for measuring pressure distribution to determine the driving influence on drag and stability.

4) A4 rocking model to determine the resonance between oscillating frequencies (about the transverse axis) and the rotations frequencies in a vertical measuring strip.

5) A4 - Jet model without tail unit to determine the spreading out of the jet as a function of the air density.

6) 2 A4 nose models for oscillation measurements to examine their stability when flying singly after being released from the projectiles.

Photograph 10.

1) 15 cm shell model for throwing on the roll moments balance.

2) Pressure distribution cone with 60° opening angle

3) " " " " 42° " "

4) " " " " 40° " "

5) " " " " 20° " "

6) Plummet for total and static pressure measurements.

7) Cone on the force measurement holder

8) Cone for pressure distribution measurements.

9) 5 different profiles for oscillation measurements to determine the pressure po[illegible]

10) Thrust diffusor model with interchangeable nozzles.

11) Projectile with thrust diffusor.

12) Tail fins from the A4 without air rudders

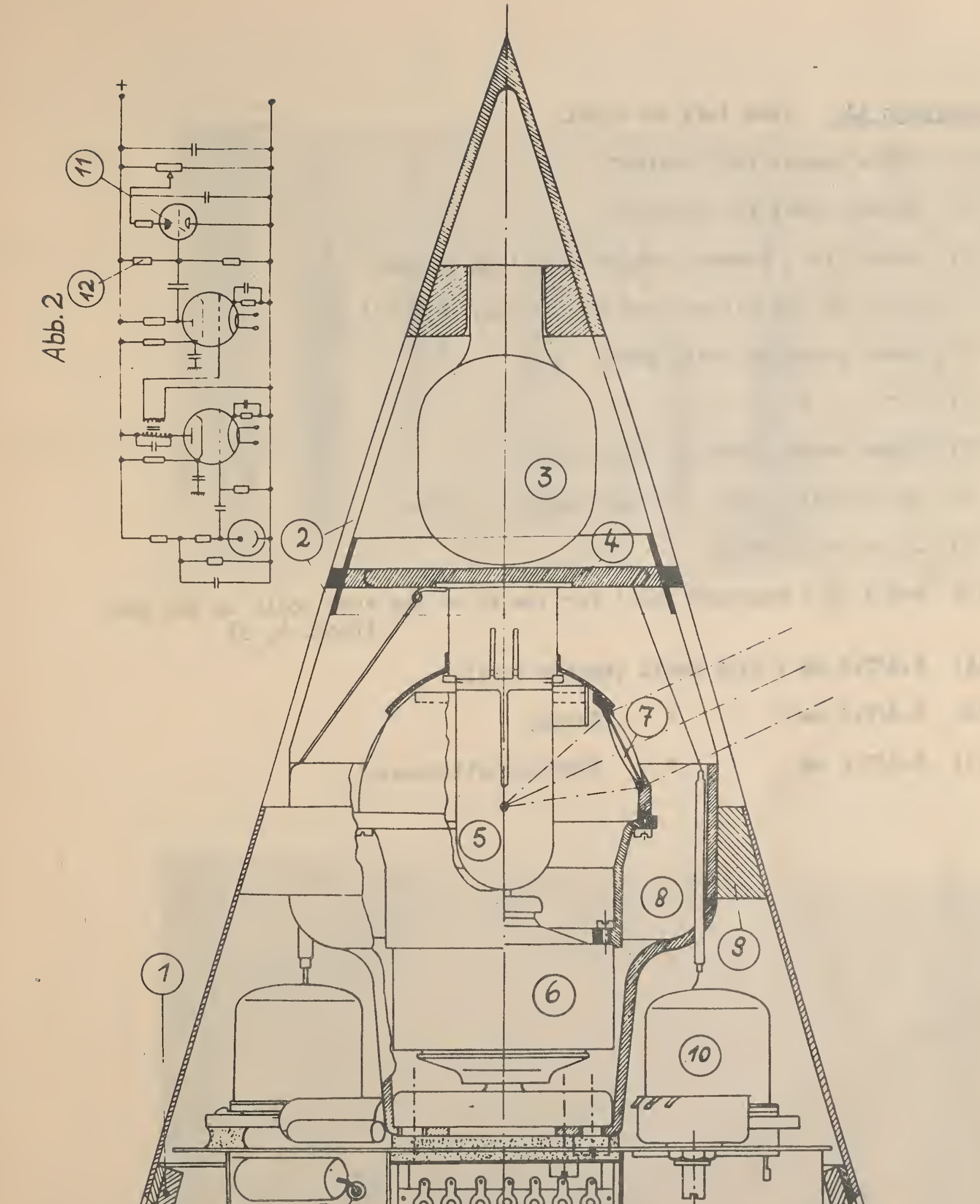


Abb. 2

Photograph 11. From left to right.

1) DOV - rocket for "Weifer"

2) Puppet model for mortars

3) Model for a forward staged anti-tank weapon

4) Model of the flying bomb SC 50 (Fins with "Sicken"

5) Armor piercing shell model

6) " " " "

7) Tiger armor piercing shell model

8) 28 cm shell model with axis parallel ribs

9) 15 cm shell model

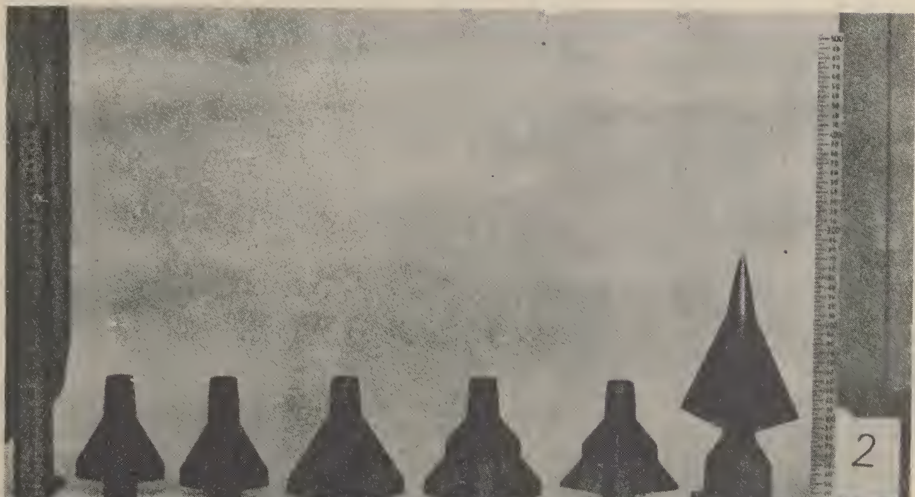
10) Model of a standard shell for the K5 on the same scale as the PPG (Phot. 6, 3)

11) 8.8/7.2 cm T Flak Shell (Bochum Verei)

12) 8.8/7.0 cm " " " (Stock)

13) 8.8/7.0 cm " " (Rheinmetall-Borsig)


1

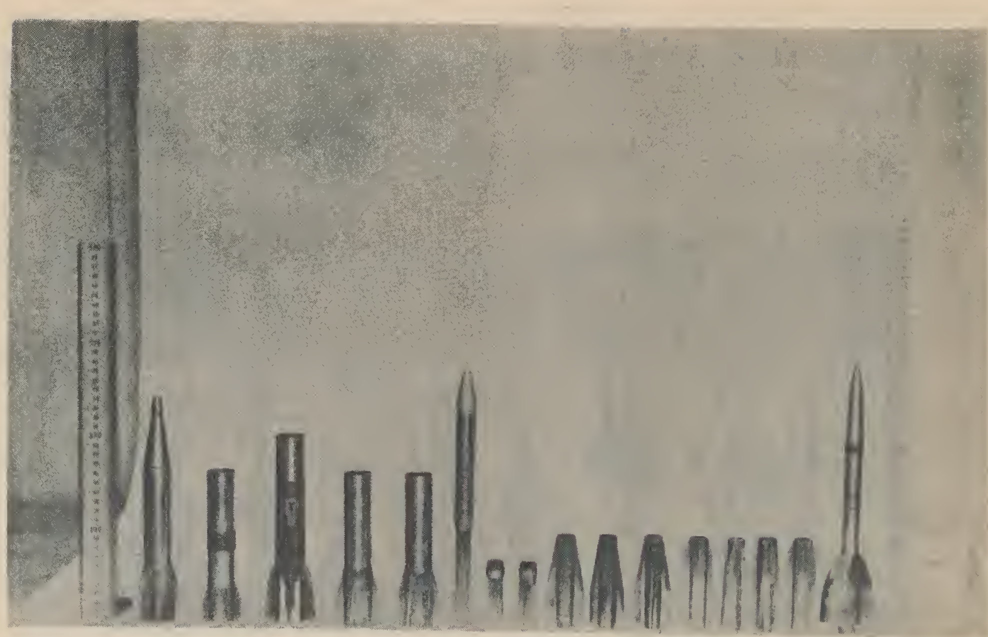

2


3


4

5

6




9

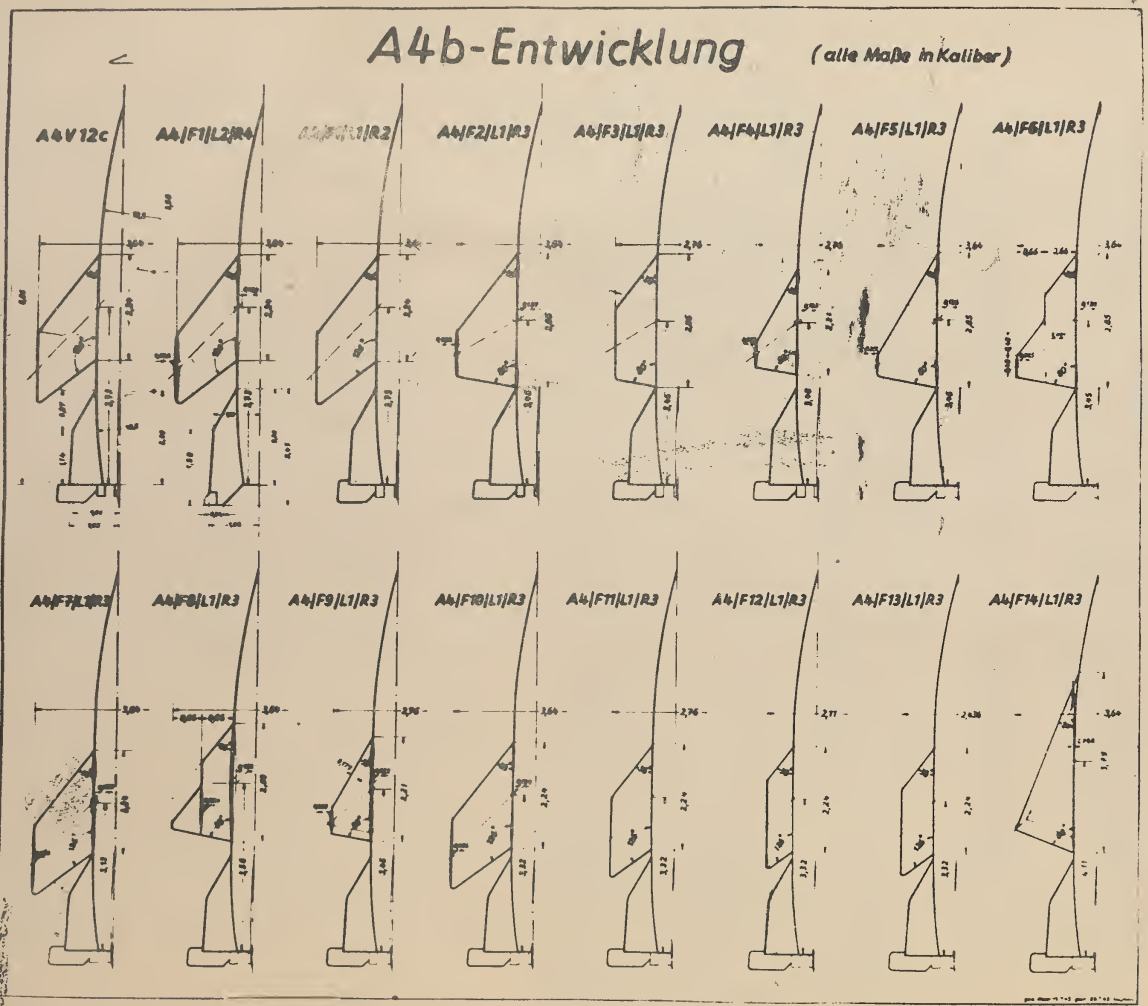

11

Zusammenstellung der Abbildungen
über bisherige Untersuchungsergebnisse
aus dem Bericht Archiv Nr 190:

Die aerodynamische Entwicklung der Fernrakete A9 (A4b)

Sachbearbeiter: Dr. Lehnert

Report #190 ordered by
Lt. Col. O'Mara, just finished
and will be forwarded along
with the rest of Kochel
internal reports at the
earliest possible moment.
These illustrations give
idea of coverage.
Lt. Col. [illegible]


A4b-Entwicklung
(alle Maße in Kaliber)
A4V12c
A4/F1/L2/R4
A4/F2/L1/R3
A4/F3/L1/R3
A4/F4/L1/R3
A4/F5/L1/R3
A4/F6/L1/R3
A4/F8/L1/R3
A4/F9/L1/R3
A4/F10/L1/R3
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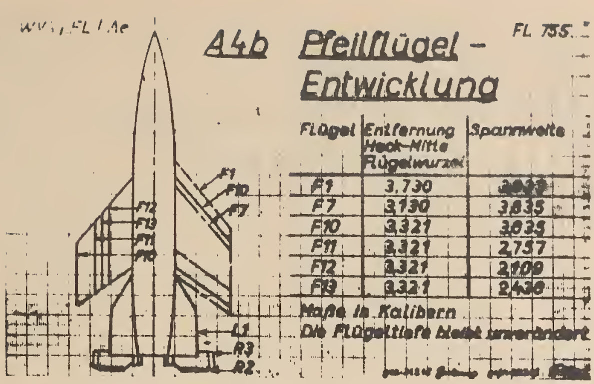
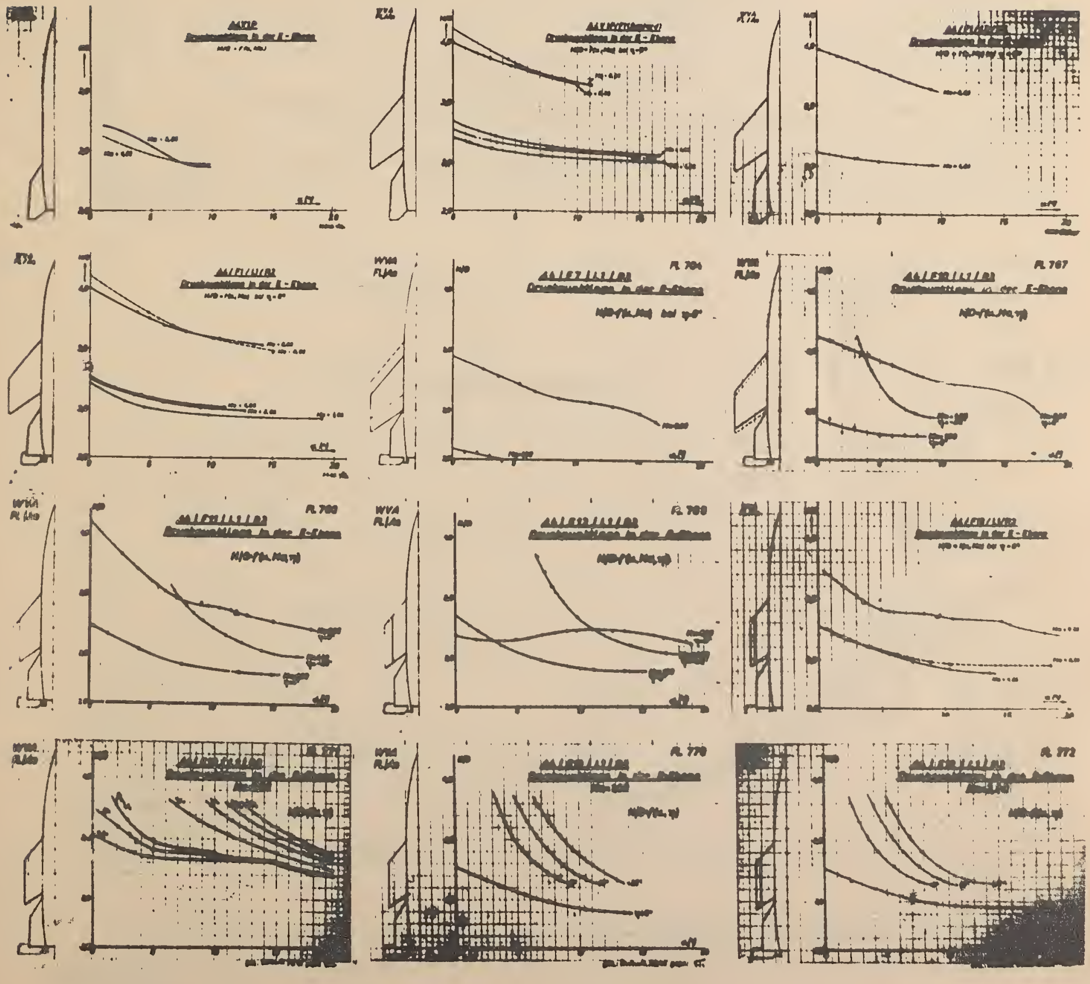
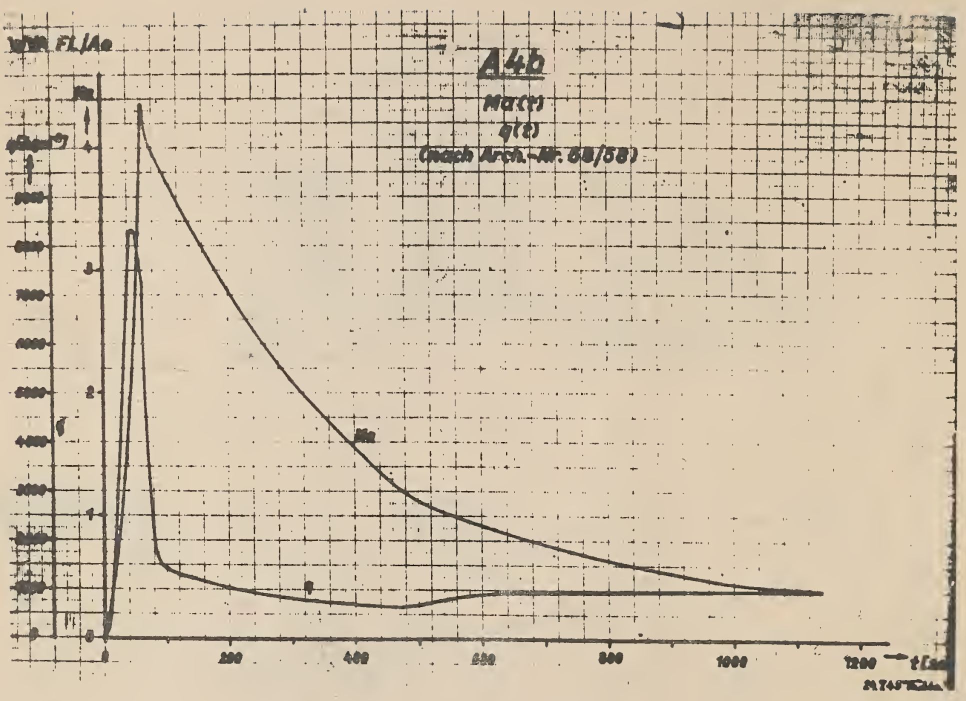
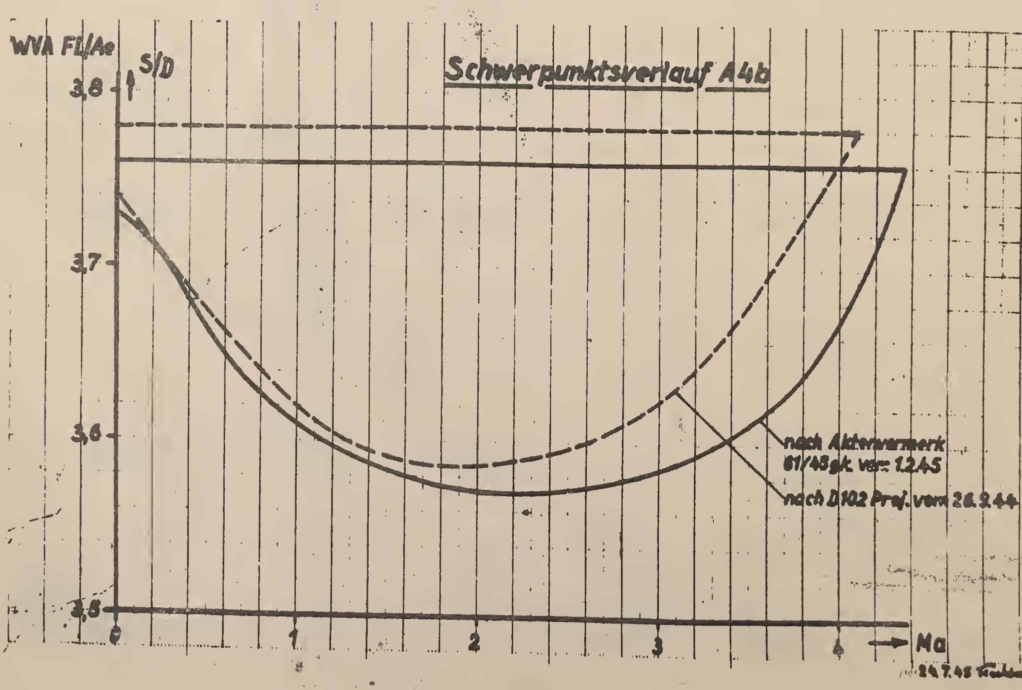
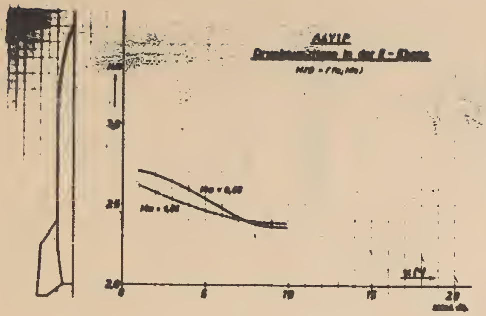
A4/F13/L1/R3
A4/F14/L1/R3

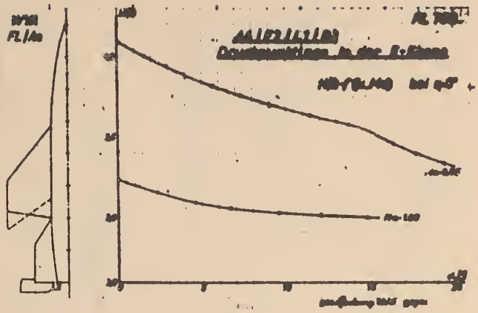

WVA FL/Ae
A4b Pfeilflügel - Entwicklung
FL 755
Flügel
Entfernung Heck-Mitte Flügelwurzel
Spannweite
F1 3,730
F7 3,130 3,835
F10 3,321 3,835
F11 3,321 2,757
F12 3,321 2,109
F13 3,321 2,430
Maße in Kalibern
Die Flügeltiefe bleibt unverändert
F1
F10
F7
F12
F13
F11
F10
L1
R3
R2

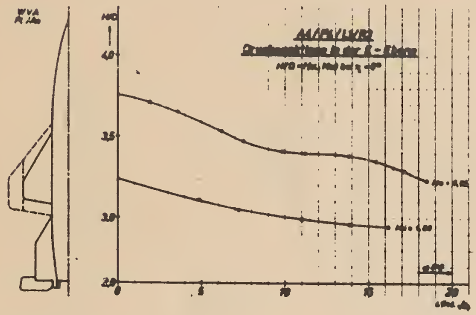


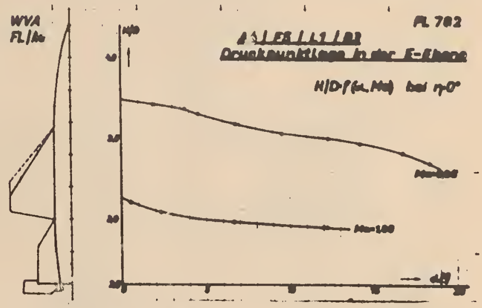

WVA FL/Ae
A4b
Ma(t)
q(t)
(nach Arch.-Nr. 66/58)
Ma
q
200
400
600
800
1000
1200

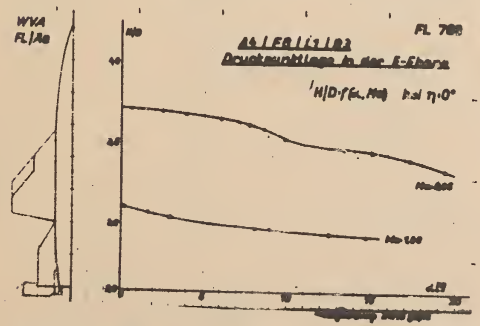

WVA FL/Ae
S/D
Schwerpunktsverlauf A4b
3,8
3,7
3,6
3,5
0
1
2
3
4
Ma
nach Aktenvermerk
61/45 g.K. vom 1.2.45
nach D10.2 Proj. vom 26.9.44
24.7.45

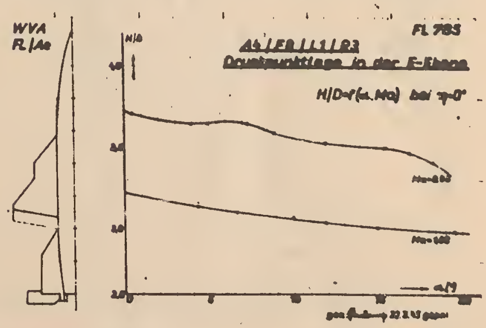

Druckpunktlage in der E-Ebene

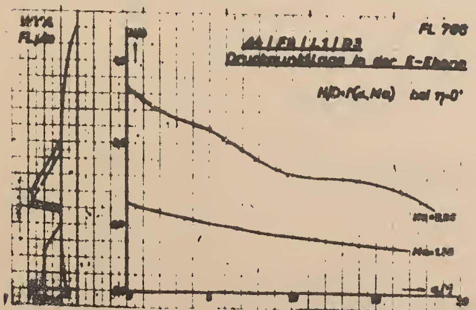

WVA
FL/Ae
Druckpunktlage in der E-Ebene
Ma=1,00

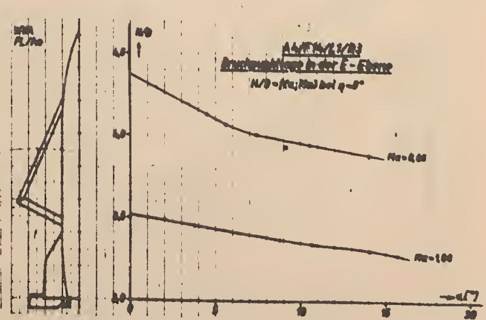

WVA
FL/Ae
Druckpunktlage in der E-Ebene

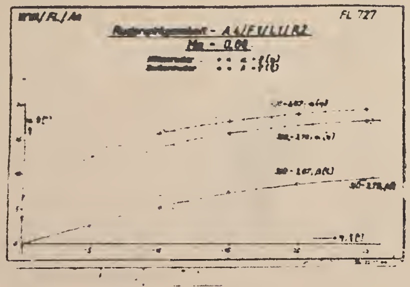

WVA
FL/Ae
FL 782
Druckpunktlage in der E-Ebene
H/D=f(α,Ma) bei η=0°
Ma=1,00

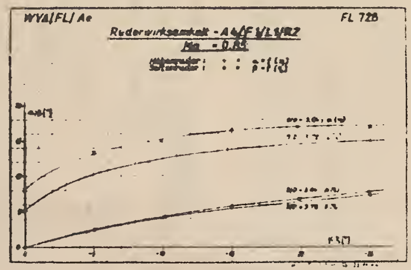

WVA
FL/Ae
Druckpunktlage in der E-Ebene
H/D=f(α,Ma) bei η=0°
Ma=1,00

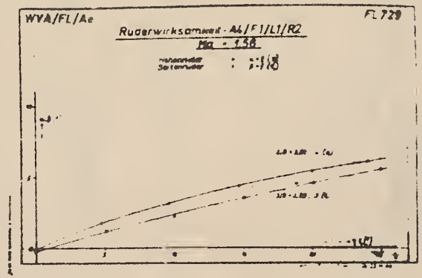

WVA
FL/Ae
FL 785
Druckpunktlage in der E-Ebene
H/D=f(α,Ma) bei η=0°

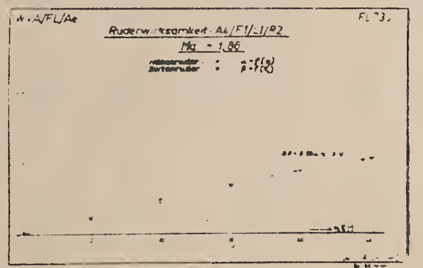

WVA
FL/Ae
Druckpunktlage in der E-Ebene
H/D=f(α,Ma) bei η=0°

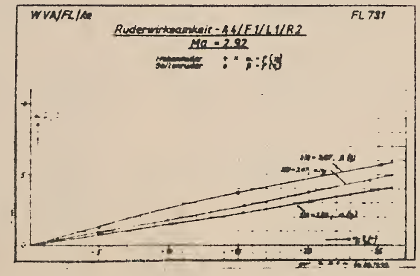

Druckpunktlage in der E-Ebene
Ma=1,00

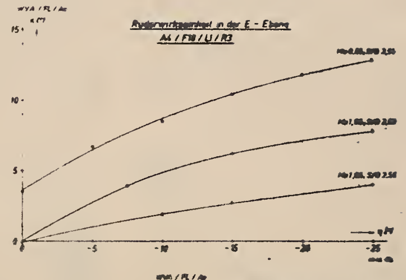

WVA/FL/Ae
FL 727
Ruderwirksamkeit - A4/F1/L1/R2
Ma - 0.60

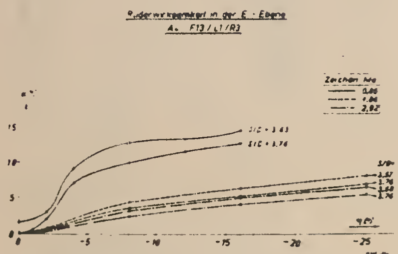

WVA/FL/Ae
FL 728
Ruderwirksamkeit - A4/F1/L1/R2
Ma - 0.85

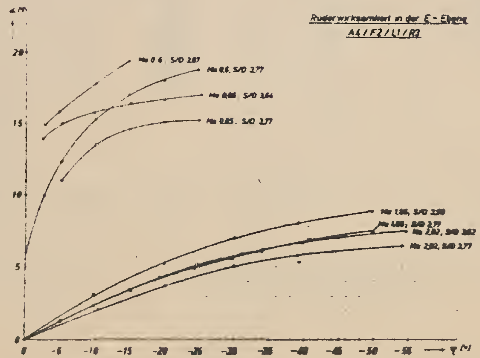

WVA/FL/Ae
FL 729
Ruderwirksamkeit - A4/F1/L1/R2
Ma - 1.58

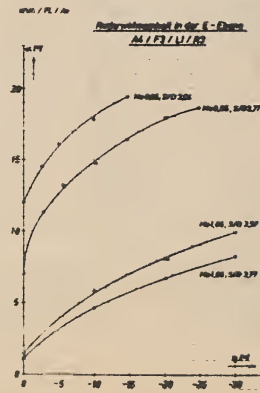

Ruderwirksamkeit - A4/F1/L1/R2
Ma - 1.86

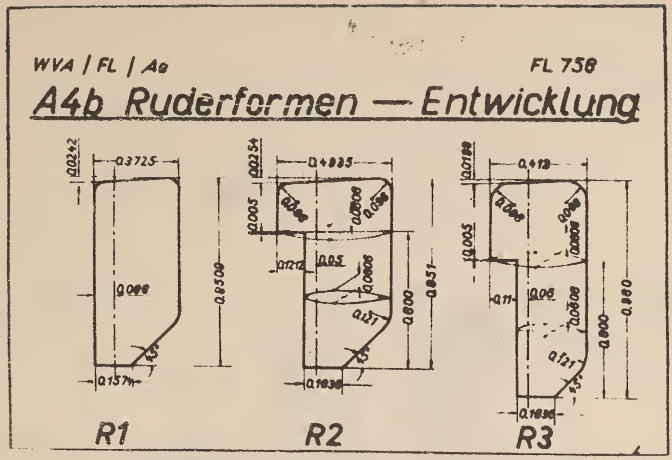

WVA/FL/Ae
FL 731
Ruderwirksamkeit - A4/F1/L1/R2
Ma - 2.92

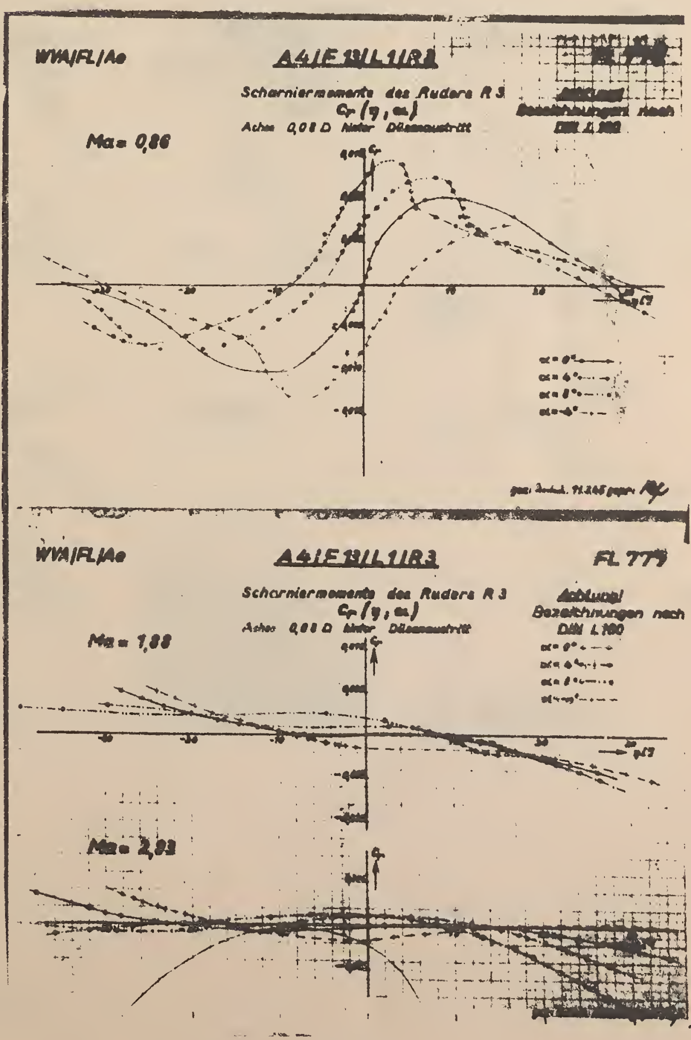

Ruderwirksamkeit in der E - Ebene
A4/F18/L1/R3

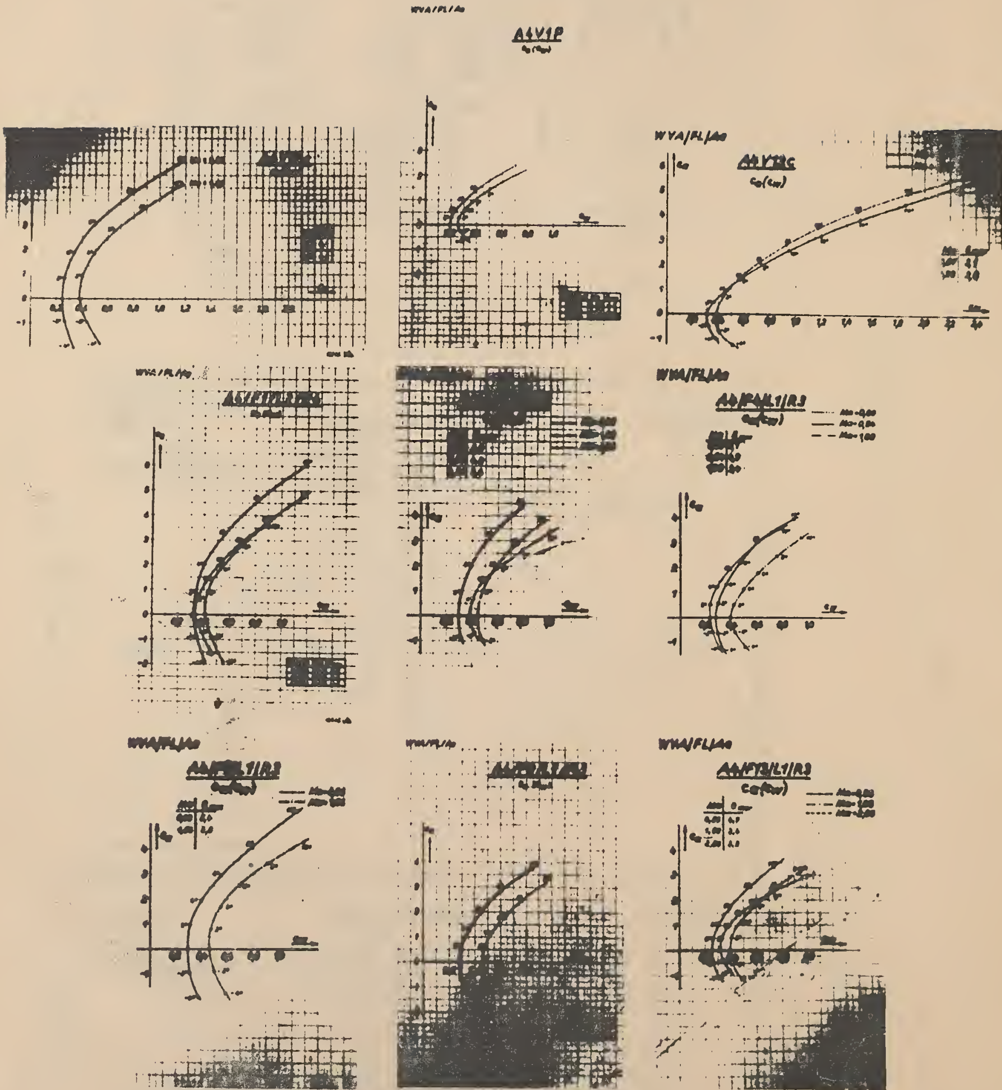

Ruderwirksamkeit in der E - Ebene
Zeichen Ma
0,60
1,86
2,92


Ruderwirksamkeit in der E - Ebene
A4/F2/L1/R3


Ruderwirksamkeit in der E - Ebene
A4/F3/L1/R3


WVA / FL / Ae
FL 758
A4b Ruderformen — Entwicklung
R1
R2
R3


WVA/FL/Ae
Scharniermomente des Ruders R 3
Ma = 0,86
WVA/FL/Ae
A4/E 13/L1/R3
Scharniermomente des Ruders R 3
Bezeichnungen nach
Ma = 1,88


WVA/FL/Ao
A4V1P

3.64
1
2.64

2.24

38
126

$2.24 - 1.32 \cot 38^\circ + 1.32 \cot 54^\circ$

(1.28) .727

1280
727
.553

.732
1.508
2.24
3.75

$1.875 \times 2.64 = \frac{4.96}{\frac{\pi}{4}} = 6.38$

$2.85 - 1.32$ 38° 50°

1.937
.928
2.85
3.77

1280
.176
1456

$\times 2.64$
1.89

.213
6.35

1.5) .036 (024

2.2) 109

$\frac{1}{1.8} =$

= .535

30 80

93.1 to 6110

9.0 to 6510

Drag 0°

M 0.86 | | M 1.86 |

C_D	0190	C_D 0.255	no wing
0060	0250	0.380	AYV12
0120	0210	0410	AYF1L2
0100	0290	0.450	AYF2L1R
0040	0230	0.400	AYF4L1R
0110	0300	0.450	AYF6L1R
0090	0280	0460	AYF9L1R
0060	0250	0395	AYF13L1R

ΔC_D

0094	AYV12C	.125	6.38	0194
	F1L2R4	.155		0244
	F2L1R	.195	7.13	0274
	F4L1R	.145		
	F6L1R	.195		
	F9L1R	.205		
	F13L1R	.140		

WVA E L		Archiv Nr. 171 g.Kdos

Story of Peenemünde
pp 12–58

. Ausfertigung

Die aerodynamische Entwicklung der Flakrakete „Wasserfall".

Der Bericht umfaßt 37 Seiten.

Wasserbau-Versuchsanstalt G.m.b.H.
München 2 BS, Postschließfach 60

München, den 15. März 1945.

Abteilungsleiter und Verfasser
Dr. Kurzweg

Direktor
Dr. Hermann

Inhalt:

Die Durchführung der zahlreichen Einzeluntersuchungen und Messungen lag in den Händen der im Literaturverzeichnis aufgeführten Sachbearbeiter unter der Leitung des Verfassers. Herr Dr. Wegener hat sich besonders bei der Durchsicht des Manuskripts und der Zusammenstellung der Abbildungen verdient gemacht.

1) Die Aufgabenstellung

Als Anfang 1943 an unser damaliges aerodynamisches Institut in Karlshagen die Forderung nach einer aerodynamisch einwandfreien Form für eine Flakrakete gestellt wurde, standen wir vor einer Aufgabe, zu deren Lösung neue aerodynamische Wege beschritten und damit umfangreiche Windkanalmessungen durchgeführt werden mußten. Der taktische Zweck erforderte ein Gerät, das bei einem Durchmesser von etwa 90 cm 9 Kaliber lang sein, mit der Geschwindigkeit Null starten, die dreifache Schallgeschwindigkeit und 20 km Höhe erreichen, vom Boden aus bis auf 50 km Entfernung steuerbar oder mit einem Zielsuchgerät ausgerüstet sein und dabei gewisse kleinste Kurven beschreiben sollte, um dem feindlichen Flugzeug nachzufliegen und ihm selbst bei Ausweichbewegungen zu folgen. Ein Aggregat, das diese Bedingungen alle erfüllt, muß teils Geschoß teils Flugzeug sein. Ein Flugzeug aber, das mit Überschallgeschwindigkeit fliegt, gab es noch nicht.

Bei der aerodynamischen Entwicklung dieser Flakrakete konnten wir uns lediglich auf unsere Erfahrungen stützen, die wir bei der Entwicklung des Aggregates A 4 gesammelt hatten. Denn A 4 ist das erste und bisher einzige Raketengeschoß, das den weiten Geschwindigkeitsbereich mit der Anfangsgeschwindigkeit v = 0 m/sec bis zur Endgeschwindigkeit v ~ 1500 m/sec durchfliegt und die Schallgeschwindigkeit einwandfrei passiert. Auch steuerungsseitig lagen hier schon Erfahrungen vor.

Es wurde deshalb – auch um keine Zeit zu verlieren – für die Flakrakete Wasserfall die Grundform des A 4, die äußere Gestalt des Leitwerks und dessen Anordnung weitgehend übernommen. Steuereinrichtungen in Form von Luftrudern mußten erst entwickelt werden. Gewisse Erfahrungen darin – allerdings nur im Windkanal – lagen an einem Gleitermodell vor, das als Weiterentwicklung des A 4-Gerätes im Projekt bereits bearbeitet worden war.

Die Forderung engen Kurvenfluges auch bei den sehr großen Geschwindigkeiten setzte die Anbringung von Tragflächen voraus, mit denen die benötigten Auftriebskräfte erzielt werden sollten. Zu den vier Leitwerksflächen, die in zwei zueinander senkrechten Ebenen angeordnet sind, wurde – von der üblichen Flugzeugform abweichend – ein symmetrisches Kreuzflügeltragwerk am Körper angebracht, um ein schnelles Einschwenken der Rakete in alle notwendigen Flugrichtungen zu ermöglichen. Der letzte Gedanke führte vorübergehend zur Untersuchung eines den Grundkörper konzentrisch umgebenden ringförmigen Tragflügels, der dem allseitigen, leichten Abkippen der Rakete am besten Rechnung getragen hätte. Der hohe Widerstand jedoch schloß die Verwendung schon nach den ersten Windkanalmessungen aus.

Die Flakrakete sollte auf Grund statischer Untersuchungen bis zum Lastvielfachen 12 bei einem Leergewicht von ~ 1,5 to belastet werden, das ja nicht unwesentlich höher sein mußte, als das des zu bekämpfenden Flugzeugs. Die Lastvielfachen der einzelnen Typen sind in folgender Tabelle angegeben:

Typ	Lastvielfaches
Jagdflugzeuge - Sturzbomber	6 - 8
Zerstörer	5 - 7
Gleitbomber	3 - 5
Horizontalbomber und Transportflugzeuge	2 - 3

Es ergab sich somit für die aerodynamische Formgestaltung, daß ein Auftriebswert von 18000 kg erreicht werden mußte. Aus den berechneten Flugbahnen mit zunächst angenommenen aerodynamischen Beiwerten, einem Schub von 8 to, einer Brennzeit von 45 sec und einer Flugzeit von 90 sec ging hervor, welche maximalen Staudrücke erreicht werden, die von der Flughöhe, von der Art des Schusses - ob senkrecht oder schräg - abhängig sind. Abb. 1 zeigt das Schußbahnbild mit den gemessenen aerodynamischen Beiwerten. Der Verlauf der Auftriebsbeiwerte von Körper und Leitwerk über dem Anstellwinkel und der Machschen Zahl aus der A 4-Messung war bekannt. Damit wären sehr große Anstellwinkel mit untragbarem Widerstand und ungünstiger Querkraftsverteilung für die Wasserfallrakete notwendig gewesen. Es ergab sich schließlich die Forderung für Unterschall 15°, für Überschall 8° Anstellwinkel. Es handelte sich also darum, Tragflügelflächen zu entwickeln, die das fehlende c_a aufbrachten, wobei für das gesamte Aggregat eine hinreichend gute Polare, d.h. beim notwendigen Auftrieb geringer Luftwiderstand erreicht würde.

Eine weitere aerodynamische Bedingung bestand darin, den Druckpunkt des Gesamt-Aggregates möglichst in allen Geschwindigkeitsbereichen konstant zu halten, da damit die Anforderungen an die Steuermaschine gering gehalten werden konnten. Jeder rotationssymmetrische, langgestreckte Körper ohne angebaute Flächen besitzt eine Druckpunktswanderung zwischen Unter- und Überschall. Auch Körper, die am Heck mit Leitwerk ausgerüstet sind, wie das A 4, zeigen diese Druckpunktswanderung, s. Abb.6 unten, die verhältnismäßig großen Spielraum in den Steuerkräften erfordert. Da das auszusteuernde aerodynamische Moment sich aus Normalkraft des Aggregates und Luftkrafthebelarm zusammensetzt, muß die Steuermaschine zur Betätigung der Luftruder für den maximalen Hebelarm ausgelegt werden. Außerdem kommt hinzu, daß die Ruderwirksamkeit im Überschall mit zunehmender Machscher Zahl stark nachläßt, wie in der weiter unten beschriebenen Abb. 8 zu erkennen ist. Gelang es, den Druckpunkt möglichst konstant zu halten und ihn nahe hinter den Schwerpunkt zu legen, so war eine kleinste Dimensionierung der Luftruder möglich. Die geringsten Steueranstrengungen wären ja dann erforderlich, wenn es gelänge, Druckpunkt und Schwerpunkt an die gleiche Stelle der Körperachse zu legen. Diese ideale Lage kann jedoch nicht erreicht werden, da einmal beim Schwerpunkt selbst durch das Entleeren der Tanks eine gewisse Wanderung nicht vermieden werden kann, s. Abb.1, zum anderen eine Druckpunktskonstanz mit zunehmendem Anstellwinkel des Körpers schwer zu verwirklichen ist.

2) <u>Die Gestaltung des Grundkörpers und des Leitwerks</u>

Wie schon oben gesagt, lag die Größe des Raketenvolumens durch die Größe des Treibstofftanks, des Ofens, der Sprengladung usw. bereits bei Aufgabenstellung für die aerodynamischen Untersuchungen fest, sodaß an der Formgestaltung des Grundkörpers nach dem Vorbild vom A 4 nicht viel geändert werden brauchte. Die Länge von 8,06 Kalibern des A 4 mußte zur Unterbringung der etwas anders gestalteten Treibstofftanks, der zusätzlichen Luftdruckkugel usw. auf 8,5 Kaliber vergrößert werden. Auch wurde der Krümmungsradius des vorderen Ogivals der etwas geringeren Geschwindigkeit entsprechend auf 10 Kaliber verkleinert. Der hintere Ogivalradius mußte ebenfalls auf 10 Kaliber geändert werden. Es ergab sich also eine endgültige Körperform nach Abb. 2 c, die ein zylindrisches Mittelstück von rund 3,5 Kalibern aufweist. Am Heck befindet sich das Leitwerk in zwei zueinander senkrechten Ebenen angeordnet mit vier gleichen Flossen und vier gleichen Rudern. Der feste Teil des Leitwerks erstreckt sich 2 Kaliber vom Heckboden nach vorn, hat einen Schulterwinkel von 30° und besitzt in der Höhe des Heckbodens eine Breite von rund 2,1 Kalibern. Die Gesichtspunkte, die zur Gestaltung des Leitwerks, das vom A 4 bis auf die Luftruder übernommen worden ist, geführt haben, sind in zwei Abhandlungen beschrieben. (Lit. 1 und 2). Über die Entwicklung des Ruders wird weiter unten im Zusammenhang berichtet.

3) Die Entwicklung des Tragwerks

Der erste Entwurf des Gerätes mit der Bezeichnung C2/E1 sah ein Tragwerk in der Form nach Abb. 2 a vor. Das Leitwerk bei diesem Gerät war gegenüber A 4 im festen Teil verkleinert, dafür hatte es wesentlich breitere Luftruder bekommen. Die Messung ergab hinreichende Wirksamkeit in Bezug auf c_a, jedoch eine untragbare Druckpunktswanderung. Unter Zugrundelegung des Schwerpunktverlaufs nach Abb. 1 war im gesamten Unterschallbereich keine Punktstabilität bei $\alpha = 0°$ zu erreichen. Momentenfreie, stabile Lagen traten erst bei größeren Anstellwinkeln bei $\alpha \sim 15°$ bis $\alpha \sim 18°$ auf. Nach Rückversetzung der Flügel und Vergrößerung des Leitwerks und Luftruders, s. Abb. 2 d, wurde Punktstabilität bei $= 0°$ erst erreicht, als der Schwerpunkt auf S/D = 4,38 vorverlegt wurde.

Punktstabilität bei $\alpha = 0°$ wurde auch erreicht, als das Tragwerk versuchsweise noch weiter zurückversetzt wurde, sodaß die Flügelmitte sich auf 3,72 D von Düsenhinterkante befand. Diese Lage ist mit Rücksicht auf die dadurch bedingte starke Rücklage des Druckpunktes im Überschall nicht tragbar. Im Überschall wurde mit dem Modell Abb. 2 a mit dem Schwerpunktsverlauf nach Abb. 1 bei allen Machschen Zahlen ebenfalls keine Punktstabilität bei $\alpha = 0°$ festgestellt. Erst das Modell nach Abb. 2 d brachte diese. Allerdings traten hierbei auch noch andere labile und stabile Lagen bei größeren Anstellwinkeln auf, auf die hier nicht näher eingegangen werden soll.

Es war also bei den genannten Modellen, wenn es auch gelang, durch Verlegung von Tragwerk und Schwerpunkt Stabilität zu

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erreichen, eine Druckpunktsdifferenz zwischen Unter- und Überschall nicht zu vermeiden. Legte man den Schwerpunkt so weit vor, daß Stabilität in jedem Falle erreicht wurde, entstanden sehr große Luftkrafthebelarme im Überschallbereich und damit untragbare Steuermaschinenbelastung. Einigte man sich dagegen auf eine mittlere Schwerpunktslage, wobei ihre konstruktive Verwirklichung noch fraglich war, so mußte die Steuermaschine im Unterschall Labilität aussteuern. Die vorliegende Steuermaschine war in dem Maße dazu jedoch nicht in der Lage.

Es mußte also versucht werden, diese Druckpunktsdifferenz zu beseitigen. Dies konnte nur durch grundlegende Umgestaltung des Flügels geschehen. Die weitere Untersuchung führte zu einer Flügelgestaltung, die weitgehende Gleichheit zwischen Leit- und Tragwerk aufweist. Das Modell trägt die Bezeichnung C2/E2. 23 weitere Zwischenformen führten nicht zum Ziel. Die Flügel haben ihre größte Erstreckung, ebenso wie das Leitwerk in der Strömungsrichtung und eine Spannweite von nur 2 Kalibern, s. Abb. 2 b, 2 e und 3. Es wurden an dieser Form neben Dreikomponenten- und Stabilitätsmessungen auch Druckverteilungsmessungen durchgeführt. Vergleicht man die Druckverteilungsmessungen im Unter- und Überschall, wie sie am Leitwerk der Fernrakete A 4 gemessen wurden, s. Abb. 4, so sieht man, daß im Unterschall die Hauptkräfte längs der schrägen Schulter liegen, im Überschall dagegen die Kräfte gleichmäßiger auf die gesamte Fläche verteilt sind. Die Druckverteilungsmessung am Wasserfallmodell, die zunächst einmal im Überschall und kompressiblen Unterschall ausgeführt wurde, zeigte qualitative Ähnlichkeit mit der Druckverteilung am Leitwerk des A 4. (s. Abb. 5). Man sieht, daß der Flügel im inkompressiblen Unterschall eine ähnliche Kräfteverteilung wie das Leitwerk A 4 in inkompressibler Strömung aufweist. Danach scheint es so, als ob die lange schräge Schulter der Grund dafür ist, daß der Unterschall-Druckpunkt der Fläche relativ weiter hinten liegt, als der einer Fläche z.B. rechteckigen Querschnittes. Bei der gleichmäßigen Druckverteilung im Überschall dagegen wird der Druckpunkt an sich immer weiter hinten liegen als im Unterschall. Deshalb muß die schräg nach vorn laufende Hinterkante im Überschall eine Vorverlegung des Flächendruckpunktes erwirken. Mit dieser Flügelanordnung wurde die in Abb. 6 gezeigte Druckpunktskonstanz in dem gesamten Geschwindigkeitsbereich erzielt. Genaueres wird darüber im Abschnitt 6 c ausgeführt. Obgleich der Grundkörper ohne angebaute Flächen eine z.T. beträchtliche Druckpunktswanderung über der Geschwindigkeit aufweist, wird er durch die Anbauten so beeinflußt, daß das Gesamt-Aggregat die gemessene Druckpunktskonstanz erhält. (Lit. 30).

4) Die gegenseitige Lage von Trag- und Leitwerk

Tragwerk und Leitwerk können so zueinander angeordnet werden, daß die jeweiligen Flügel- und Leitwerkspaare in gleichen Ebenen liegen. Es ist aber auch möglich, das Tragwerk gegen das Leitwerk um einen gewissen Winkel gegeneinander zu verdrehen. Am zweckmäßigsten geschieht dies um 45°, um wieder eine symmetrische Anordnung zu bekommen. Es hatte zunächst den Anschein, als wenn die letztere Form, bei der also $\Delta\varphi = 45^\circ$ ist, der ersten vorzuziehen sei. Bei kleinem Anstellwinkel wird dabei nämlich der Abstrom des Tragwerks Leitwerk und Ruder nicht treffen und damit erhöhte Stabilität des Gerätes bewirken. Bei der $\Delta\varphi = 0^\circ$-Lage wird gerade bei kleinem Anstellwinkel die Beeinflussung durch diesen Abstrom stark sein. Es hat sich jedoch herausgestellt, daß bei größeren Anstellwinkeln die Beeinflussung der unter 45° liegenden Tragwerksflächen auf die Ruder besonders stark ist und unübersehbare stabile und labile Lagen des Körpers bei Ausschlag des Ruders hervorruft. Deshalb wurde die $\Delta\varphi = 45^\circ$-Lage wieder verworfen und die $\Delta\varphi = 0^\circ$-Lage weiter untersucht. Sie ist in der Form C2/E2 (Abb. 2 b und 3) zur Anwendung gekommen. (Lit. 26).

5) Die Luftruderentwicklung

Es stand von vorn herein fest, daß die Flakrakete mit Luftrudern gesteuert werden sollte, da auch nach Brennschluß die Steuerfähigkeit des Gerätes erhalten bleiben mußte. Da in den ersten Flugsekunden der Staudruck zur Steuerung durch Luftruder allein nicht ausreicht, war eine Kopplung mit Strahlrudern vorgesehen.

Diese aus Graphit bestehenden Strahlruder sollten auf gleicher Welle mit dem Luftruder angeordnet werden und in den Antriebsstrahl hineinragen. Es war Höhen-, Seiten- und Drallsteuerung vorzusehen, wobei Höhe und Seite durch Steuerimpulse vom Boden aus ferngesteuert, der Drall durch Eigensteuerung unterdrückt werden sollte. Es wurde überlegt, den Drall durch Querruder an den Flügelenden auszusteuern. Dies hätte zwar aerodynamisch eine bessere Wirksamkeit versprochen, man wäre jedoch konstruktiv in Bezug auf die Übertragung der Kräfte von der Steuermaschine auf Schwierigkeiten gestoßen. Deshalb wurde grundsätzlich auf gesonderte Drallruder verzichtet und die Drallsteuerung mit auf die Höhen- und Seitensteuerung aufgeschaltet.

Die auszusteuernden aerodynamischen Momente, die infolge des Körperanstellwinkels auftreten, wurden zunächst überschlägig berechnet. Danach konnte die Größe der Ruderfläche wie folgt festgelegt werden: Jedes Ruder mußte im Maximalfalle eine bestimmte Normalkraft erzeugen, die an dem Hebelarm, Schwerpunkt des Körpers bis Druckpunkt des Ruders, die entsprechenden Steuermomente hervorrief. Die notwendige Normalkraft konnte nun entweder durch große Fläche bei kleinem oder kleine Fläche bei großem Anstellwinkel erzeugt werden. In letzterem Falle war mit größerem Widerstand zu rechnen. Außerdem war dabei die Gefahr des Überschreitens der Bruchlast vorhanden. (Lit. 9).

Nach Abschätzung aller Möglichkeiten ergaben sich somit folgende aerodynamischen und konstruktiven Gesichtspunkte für die Ruderentwicklung:

a) Zugelassener Ruderhöchstausschlag $\pm 25^{\circ}$
b) Höchstzulässige Rudernormalkraft 1 to je Ruder
c) Zuordnung von Ruderausschlag zu Körperanstellwinkel innerhalb folgender Grenzen:
   Unterschall: $0{,}3 \leq \frac{\eta}{\alpha} \leq 1$; Überschall: $1{,}0 \leq \frac{\eta}{\alpha} \leq 2{,}0$
d) Aussteuerung aller Bauunsymmetrien mit Ruderausschlag $\eta = 2^{\circ}$.

Weitere Forderungen an die Luftruder kamen von Seiten der Steuermaschine, die die Scharniermomente erzeugen muß. Die Größe der Maschine lag anfangs noch nicht endgültig fest. Es konnten deshalb nur ungefähre Angaben über ihre Leistungsfähigkeit gemacht werden. Es wurde damit gerechnet, daß die Steuermaschinen Scharniermomente nach folgender Tabelle würden bewältigen können:

Rudermaschine K 12, Achse $S_R = 0{,}08\ D$ $M_{R\ max} = 35$ mkg

Primitivsteuerung, Achse $S_R = 0{,}057\ D$ $M_{R\ max} = 50$ mkg

Es wurde angenommen, daß die Steuermaschine auch negative Scharniermomente von etwa 2/3 des positiven Betrags leisten würde.

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Unter Berücksichtigung aller angeführten Forderungen wurde nun eine große Reihe von Ruderformen (Lit. 13, 25) untersucht, wobei sich schließlich das Luftruder R 12, s. Abb. 2 f, ergab, das zunächst allen Anforderungen genügte. Man sieht aus den Messungen nach Abb. 7 linke Seite, daß die Scharniermomentenkurven im Überschall bei allen Machschen Zahlen stets positive Tangenten haben, daß sie dagegen im Unterschall starke Labilität aufweisen. Die mit diesem Ruder erhaltenen Wirksamkeitskurven $\alpha = f(\eta)$ sind in der Abb. 8 oben dargestellt. (Lit. 12,16). Man sieht daran, daß sämtliche Überschallkurven bis zu einem Winkel von $\eta = 25^\circ$ mit stetiger, positiver Tangente verlaufen. Die Wirksamkeit nimmt mit zunehmender Geschwindigkeit ab. Die Wirksamkeit im Unterschall ist ebenfalls einwandfrei, wenn der Körper unter $\varphi = 0^\circ$, d.h. in einer Leit- oder Tragwerksebene fliegt. Kippt der Körper jedoch unter 45° zu Leit- und Tragwerkskreuz ab, dann weisen die Wirksamkeitskurven bei einem Winkel von etwa $\alpha > 15^\circ$ einen S-Schlag auf, der Labilität des Körpers in dem betreffenden Anstellwinkelbereich bedeutet. Es gibt also zu einem bestimmten Ruderausschlag zwei zugehörige Anstellwinkel, s. auch Abb. 9 oben, wo c_m über α aufgetragen ist. Es wurde versucht, durch verschiedene Ruder- und Leitwerksgestaltung und Änderungen am Flügel diesen S-Schlag zu beseitigen. Die bisherigen Untersuchungen waren jedoch noch nicht befriedigend. Es wird darüber an anderer Stelle berichtet. (Lit. 26). Der Grund dafür liegt eindeutig in der Beeinflussung von Leitwerk und Ruder durch die davor liegenden Flügelflächen. Derartige S-Schläge würden wahrscheinlich nicht auftreten, wenn der Körper mit dem festen Teil des Leitwerks ohne die Ruderfläche allein stabil wäre. Das würde jedoch eine stärkere Rückverlegung des Druckpunktes und damit für die Steuermaschine größere Leistung erfordern, sofern nicht durch eine Hilfsrudereinrichtung die Steuerkräfte wesentlich herabgesetzt werden könnten. Versuche dieser Art sind bei der WVA im Gange. (Lit. 23). Das Auftreten des S-Schlages ist jedoch in diesem Anstellwinkelbereich für das vorliegende Wasserfallgerät nicht unbedingt kritisch, da nur im Ausnahmefall der Körper mit dem Anstellwinkel $\alpha > 15^\circ$ im Unterschall in der $\varphi = 45^\circ$-Lage abkippen wird. Der Ausnahmefall tritt auf bei Knüppelfehlern, Pendelungen um die

Sollbahn oder Böen. Da die Beseitigung des S-Schlages in allernächster Zeit nicht zu erwarten ist, muß diese Unsicherheit in Kauf genommen werden.

Eine genaue steuermaschinenseitige Untersuchung auf dem Schwingtisch ergab, daß die Absolutwerte der negativen Scharniermomente herabgesetzt werden mußten, ebenso mußte das negative $\frac{dc_R}{d\eta}$ verkleinert werden. Es wurde daher die Flügeltiefe des Ruders gekürzt, sodaß die Ruderfläche sich um 25 % verringerte. Dies war gleichzeitig insofern zweckmäßig, als beim R 12 der Ruderhöchstausschlag von $\eta = 25^\circ$ nicht ausgenutzt werden konnte. Das neue Ruder erhielt die Bezeichnung R 21, s. Abb. 2 g. Die Scharniermomente sind in Abb. 7 rechte Seite, die Ruderwirksamkeitskurven in Abb. 8 dargestellt. Man sieht, daß die Forderung des Herabsetzens des negativen Scharniermoments und die Verringerung der Steilheit von $\frac{dc_R}{d\eta}$ erfüllt wurde. (Lit. 24). Das Aggregat mit dem Ruder R 21 erhielt die Bezeichnung C2/E3.

6) Die Meßmethoden und die Meßergebnisse

Die Untersuchungen im Windkanal erstrecken sich einmal auf solche im inkompressiblen Unterschall, wobei Modelle von ~ 1,30 m Länge bei etwa 40 m/sec in Kanälen von etwa 3 m Ø gemessen wurden. (Luftschiffbau Zeppelin und Luftfahrtforschungsanstalt München). Dabei wurden Dreikomponenten- und Schwingungsmessungen, Scharnier- und Drallmomentenmessungen durchgeführt. Zum anderen erstreckte sich der Hauptteil der Untersuchungen auf Modelle von 180, 266 und 315 mm Länge im Windkanal der WVA bei 40 cm² Querschnitt und bei Geschwindigkeiten von etwa 0,4 facher bis 0,9 facher sowie bei der 1,2-fachen, 1,6 fachen, 1,9 fachen, 2,5 fachen und 2,9 fachen Schallgeschwindigkeit. Auch im Überschallwindkanal der WVA wurden Dreikomponenten- und Schwingungsmessungen, Scharnier- und Drallmomentenmessungen durchgeführt. Zur Ermittlung der Steuermomente kam außerdem eine neuartige Nullmomentenmethode zur Anwendung. Weiterhin fanden umfangreiche Druckverteilungsmessungen über die gesamte Körperoberfläche statt.

a) Dreikomponentenmessungen

Das Modell wurde dabei von hinten mit einem 2-teiligen Halter im Heckboden gehaltert, dessen erster Teil an die Waage führte und dessen anderer Teil zur Blendenmessung diente, s. Abb. 10 a. Es wurden zwei Widerstandskomponenten und eine Auftriebskomponente gemessen. (Lit. 4, 6, 7, 10, 15). In den Abb. 11 - 14 sind die dimensionslosen Beiwerte des Widerstands c_w und des Auftriebs c_a über der Machschen Zahl dargestellt. Der Verlauf des Luftangriffspunktes H/D = f(Ma) ist in Abb. 6 enthalten. Die Abb. 15 zeigt eine Abhängigkeit von c_a und c_w über dem Anstellwinkel einmal im Unterschall bei der Machschen Zahl 0,84, das andere Mal im Überschall bei Ma = 2,92. Die Polaren bei den einzelnen Geschwindigkeiten sind in den Abb. 16 und 17 dargestellt. Man sieht, daß die maximalen Gleitzahlen c_a/c_w im Überschall 3, im Unterschall 4,4 sind. Im Überschall oberhalb Ma = 1,2 können die Gleitzahlen nur aus den extrapolierten Polaren angegeben werden, da die Tangenten bis zu den letzten Meßwerten ihr Maximum noch nicht erreicht haben. Neben den Kraftmessungen sind laufend photographische Strömungsaufnahmen mit der Schlieren-Apparatur durchgeführt worden. Sie geben ein qualitatives Bild der Strömungsausbildung, s. Abb. 18.

b) Schwingungsmessungen

Das Modell wurde dabei im Schwerpunkt durch einen quer zur Strömungsrichtung ausgespannten Draht, der bis zum Körper durch ein Zweiecksprofil verkleidet war, gehalten, sodaß es Schwingungen in einer senkrechten Ebene ausführen konnte. (Abb. 10 b). Dabei wurden einmal nach dem Abklingen der Schwingungen die Endlagen photographiert und aus dem Lichtbild die Anstellwinkel ausgemessen, zum anderen wurden die Schwingungen mittels Registrierkamera aufgenommen und die Oszillogramme auf Momente, Druckpunktslage, Normalkräfte und Dämpfung ausgewertet. (Lit. 17).

Aus den Schwingungsmessungen ergaben sich folgende Eigenschaften des Modells:

Bei Verdrehung des Tragwerks um 45° gegen das Leitwerk, um möglichst geringe Beeinflussung der Ruder durch den Abstrom der Flächen zu erzielen, ist bei kleinen Anstellwinkeln Stabilität vorhanden, bei größeren Winkeln gibt es jedoch labile, und bei noch größerer Auslenkung wieder stabile Lagen. Auch bei der Rückverdrehung des Tragwerks auf $\Delta \varphi = 0^\circ$ treten bei höheren Anstellwinkeln zwischen $\alpha = 15^\circ$ und $\alpha = 30^\circ$ charakteristische Änderungen von $\frac{dc_m}{d\alpha}$ auf, wenn die Anströmung unter $\varphi = 45^\circ$ erfolgt. Diese Änderungen sind z.T. derart, daß die positive Charakteristik in eine negative übergeht und anschließend wieder ihr Vorzeichen wechselt. Beim Ruderanstellwinkel 0° ist der Körper dabei immer stabil. Werden die Ruder jedoch angestellt, dann entstehen momentenfreie Körperlagen mit stabilem oder labilem Gleichgewicht. Die Abb. 9 zeigt einen solchen Fall bei der Unterschallgeschwindigkeit von Ma = 0,1 an einem großen Modell von ~ 1,30 m Länge. Hier ist zu erkennen, daß bis zu einem Ruderanstellwinkel von $\eta = -6^\circ$ noch immer Punktstabilität des Geräts vorhanden ist trotz des Vorzeichenwechsels der Tangente bei $\alpha = 19{,}5^\circ$, daß jedoch schon bei $\eta = -7^\circ$ drei momentenfreie Lagen, nämlich $\alpha = 14{,}5^\circ$, $\alpha = 22{,}6^\circ$ und $\alpha = 26^\circ$ auftreten. Es sind die gleichen, die an den kleinen Modellen gemessen wurden und in der Abb. 8 für Ma = 0,4 in der $\alpha = f(\eta)$ Kurve zu erkennen sind. In der mittleren momentenfreien Lage herrscht labiles Gleichgewicht. Für den Flug des Geräts ist dieser α-Bereich jedoch unwesentlich. Bei der Anströmung unter $\varphi = 0^\circ$ treten derartige S-Schläge in diesen Winkelbereichen nicht auf.

In Abb. 9 unten sind je zwei Momentenkurven bei Ma = 1,86 und 2,92 dargestellt, die die Momentenbeiwerte bezüglich zwei verschiedener Drehpunkte angeben. Sie wurden durch Auswertung der Oszillogramme nach einer besonderen Parabelmethode (Lit. 21) erhalten. Man sieht, daß die Kurven in einem Bereich bis $\alpha = 10^\circ$ annähernd linear verlaufen.

c) Nullmomentenmessungen

Das Modell ist dabei ebenfalls um eine senkrecht zur Strömungsrichtung befindliche horizontale Achse gelagert, die sich jedoch im Innern des Modells an einem Halter befindet, der durch das Heck in das Modell von hinten eingeführt ist. (Abb. 10 c) (Lit. 27) Diese neue Anordnung hat den Vorteil, daß keinerlei Störungen durch seitliche Halterung auf das Modell übertragen werden können. Das Modell hat zwar nur wenig Spiel, es sollen lediglich damit die momentenfreien Lagen des Körpers festgestellt werden, bei denen sich das

Modell im aerodynamischen Gleichgewicht befindet. Befindet sich also die Achse genau im Schwerpunkt des Modells, dann wird es sich mit dem Anstellwinkel $\alpha = 0^\circ$ einstellen, wenn es bei $\alpha = 0^\circ$ punktstabil ist, d.h. daß sich der Druckpunkt hinter dem Schwerpunkt befindet. Denn das aerodynamische Moment verschwindet, wenn entweder Normalkraft oder Luftkrafthebelarm = 0 ist. Gibt man andererseits ein mechanisches Moment durch Anbringung von zusätzlichen Gewichten vor, sodaß also Drehpunkt und Schwerpunkt nicht zusammenfallen, so wird sich der Körper in eine andere Ruhelage einstellen. In dieser sind das aerodynamische und das mechanische Moment, deren Drehsinn natürlich entgegengerichtet sein muß, gleich. Da diese Ruhelage je nach der Größe des vorgegebenen mechanischen Momentes bei jedem beliebigen Anstellwinkel sich einstellen kann, ist es notwendig, den Halter in seiner Lage zur Strömungsrichtung zu verfahren. Er befindet sich zu dem Zweck am gleichen Segment, das zur Dreikomponentenwaage führt, und dessen Anstellwinkel verändert werden kann. Der Anstellwinkel wird dann während des Blasens solange verfahren, bis das Modell sich von der Anlage am Halter loslöst und frei um den Halter spielt. Mit dieser Methode, bei der man die stabilen Gleichgewichtslagen auf $\pm 1^\circ$, aber auch die labilen, momentenfreien Punkte auf etwa $\pm 2^\circ$ bestimmen kann, erhält man in relativ kurzer Zeit genaueste Messungen der Druckpunktslage und Wirksamkeitskurven der Luftruder. In letzterem Fall werden die Ruder von Grad zu Grad angestellt und dabei der Anstellwinkel der Gleichgewichtslage des Körpers gemessen. Bei der Ermittlung des Druckpunktes kann mit einer Genauigkeit von $\pm$ 1/10 Kaliber gerechnet werden. Den auf diese Weise ermittelten Verlauf der Luftangriffspunkte über dem gesamten Geschwindigkeitsbereich zeigt die Abb. 6. Hier ist H/D über der Machschen Zahl aufgetragen. Die schwach eingezeichneten Werte aus der Dreikomponentenmessung und der Parabelmethode sind mit geringerer Genauigkeit, die etwa $\pm$ 1/4 Kaliber beträgt, zu werten. Man sieht, daß die Druckpunktskonstanz hinreichend gut durch die Kombination von Körper, Trag- und Leitwerk erreicht worden ist. Daß eine stärkere Druckpunktswanderung an dem Körper mit Leitwerk allein stattfindet, zeigt die Abb. 6 unten, die den H/D-Verlauf über der Machschen Zahl beim Anstellwinkel $\alpha = 8^{\circ}$ an dem flügelstabilisierten Aggregat A 4 V 1 P darstellt, dem ja die Flakrakete Wasserfall bis auf die Flügel weitgehend geometrisch ähnlich ist.

d) Druckverteilungsmessungen

Um den Konstrukteuren die Unterlagen zur Konstruktion der Zelle zu liefern, ist es notwendig, die Drücke über die gesamte Oberfläche des Körpers, der Tragflügel und des Leitwerks zu kennen. Es werden deshalb Druckverteilungsmessungen an allen Punkten der Modelloberfläche im Unter- und Überschall durchgeführt, die einen erheblichen Arbeitsaufwand erfordern. Im Über- und Unterschall - soweit letzterer im hiesigen Windkanal gemessen werden kann, etwa von Ma = 0,4 bis Ma = 0,9 - wird dabei ein besonderes Halbmodell (Abb. 10 d) benutzt, um die von den 120 Bohrungen ausgehenden Luftröhrchen möglichst ohne Störung der Strömung nach außen an die Manometer zu führen. (Lit. 3) Aus der Druckverteilung werden durch graphische Integration der Drücke über die Oberfläche Normal- und Tangentialkräfte berechnet. Nachdem die Oberflächenreibung rechnerisch abgeschätzt ist, kann sie zum Widerstandsanteil aus der Druckverteilung addiert und die Summe mit dem Widerstand aus der Kraftmessung verglichen werden. Für die Normalkräfte spielt die Oberflächenreibung besonders bei den hier infrage kommenden schlanken Körpern nur eine geringe Rolle. (Lit. 5) Die Ergebnisse der für die Wasserfallrakete durchgeführten Druckverteilungsmessungen sind in den Berichten: Lit. 14, 19, 22 festgelegt. Die Abb. 5 zeigt die Druckverteilung längs des gesamten Aggregates bei zwei Geschwindigkeiten im kompressiblen Unter- und im Überschall bei verschiedenen Anstellwinkeln. Man sieht die ausgesprochen starken Kräfte, die auf Flügel und Leitwerksvorderkante im Unterschall liegen. Im Überschall dagegen ist mit steigender Machscher Zahl eine zunehmende gleichmäßigere Verteilung auf allen Flächen zu erkennen.

Für die Konstruktion des Luftruders war es wichtig, die Verteilung der Oberflächenkräfte auf ihm zu kennen. Es wurde deshalb an einem besonderen "Teilmodell" mit wesentlich größerem Ruder, wie es auch für die Messung der Scharniermomente benutzt wurde, (s. folgenden Abschnitt) die Druckverteilung auf Luv- und Leeseite an einer größeren Anzahl von Anbohrungen gemessen. (Lit. 22). Diese Messungen gaben wesentliche Hinweise für die endgültige Formgebung des Ruders. Die Abb.19 zeigt als Beispiel eine Isobarendarstellung über der Ruderfläche.

e) Die Drall- und Scharniermomentenmessung

Eine wesentliche Vorbedingung für den einwandfreien Flug der Rakete ist ihre Drallfreiheit. (Lit. 18) D.h. es muß vermieden werden, daß die Rakete sich um ihre Längsachse drehen, und damit in eine gefährliche Resonnanz mit ihrer Querschwingungsfrequenz kommen kann. Das würde zu Taumelschwingungen (Lit. 28) führen. Außerdem vertragen die elektrischen Einrichtungen der Steuermaschine keine Drehung des Aggregates um die Längsachse. Die aerodynamischen Kräfte, die den Drall erzeugen, entstehen einmal durch die Unsymmetrie des Gerätes, da Trag- und Leitwerksflächen niemals so genau hergestellt werden können, das andere Mal durch die Schiefanblasung von Leitwerk und Flügelkreuz bei Anstellwinkeln.

Für die Drallmessungen wurde ein besonderes Drallmeßmodell angefertigt, das ähnlich dem Nullmomentenmodell von hinten im Innern gehaltert wurde. Als Meßelement war ein Torsionsdraht längs der Körperachse durch den durchbohrten Halter hindurch gespannt, mit dem die Drallmomente durch geeichte Drehung auf Null kompensiert werden konnten. (Lit. 18). Messungen des durch Unsymmetrie der Flügel- und Leitwerksflächen erzeugten Dralls zeigten eine Abhängigkeit des Dralls nach Abb. 20 rechts, in der bei Ruderanstellwinkel 0° alle Flächen gleichsinnig um 2° gegen die Körperachse angestellt wurden. Die Abb. 20 links zeigt die Meßergebnisse bei einem normal hergestellten Modell mit im Gegensinn ausgeschlagenen Luftrudern. Auffällig ist die besonders starke Wirksamkeit der Drallsteuerung, obgleich der Hebelarm Körperachse-Ruderdruckpunkt nur etwa 1 Kaliber beträgt. Zur geforderten Aussteuerung der Drallmomente durch Schränkfehler ist also nur etwa der zehnte Teil des geforderten Höchstluftruderausschlages ($\eta = 2^\circ$) nötig.

Die Scharniermomente, auf deren Größe und Bedeutung im Abschnitt 5, der sich mit der Luftruderentwicklung befaßt, schon eingegangen wurde, wurden im wesentlichen an einem Teilmodell gemessen. Da die Luftruder an den Modellen normaler Größe für den 40 x 40 cm Kanalquerschnitt relativ klein sind (nur 1 bis 2 cm^2) und damit nur absolut kleine Momente erzeugen, verzichteten wir bei der Messung auf die Anwesenheit des ganzen Körpers. Es wurde lediglich die feste Leitwerksfläche mit einem Körperstück in den Luftstrom gebracht, an der das Ruder an einer nach außen durchgeführten Achse befestigt wurde. Mit dem Maßstab dieses Modells 1:10 wäre der ganze Körper etwa 80 cm lang geworden. Diese Größe war jedoch nicht tragbar. Da die außen liegenden Luftruder sehr wenig durch den Körper beeinflußt werden durften, wurde der Körper vor dem Leitwerksbeginn abgebrochen. (Abb. 10 e) Die Ruderfläche von etwa 35 cm^2 ergab damit ausreichende Momente, die unmittelbar durch mechanische Gewichtsauflegung außerhalb des Luftstroms kompensiert werden konnten. Entsprechende Messungen an einem Halbmodell normaler Größe (Abb. 10 f) ergaben hinreichend gute Übereinstimmung mit den obigen Messungen. (Lit. 13)

7) Der Einfluß des Strahls auf die aerodynamischen Eigenschaften

Der Einfluß des Strahls auf den Widerstand wird sich genau wie bei dem Körper A 4 in einer Erhöhung im Unterschall und einer Verringerung im Überschall bemerkbar machen. Für die Größe der Beeinflussung dürfte neben der Heckausbildung das Verhältnis von Fluggeschwindigkeit zu Strahlgeschwindigkeit eine Rolle spielen. Obgleich hierüber für den Wasserfallkörper noch keine Messungen vorliegen, läßt sich sagen, daß an dem Heckogival durch den austretenden Strahl im Unterschall erhöhte Geschwindigkeit mit erniedrigtem Druck, also Sog auftritt. Im Überschall dagegen wird durch das Aufblähen der Grenzschicht eine frühere Ablösung der Strömung erreicht und der Druck auf dem Heckogival erhöht, was den Druckwiderstand verringert. Die frühere Ablösung der Grenzschicht ist im wesentlichen auf die Entstehung des Verdichtungsstoßes zurückzuführen, der beim Zusammentreffen der den Körper umströmenden Luft mit dem im Unterdruck erweiterten Antriebsstrahl (Glocke) entsteht. In Bezug auf Normalkräfte und Luftangriffspunkt kann noch nichts endgültiges ausgesagt werden.

Es wurde ein Versuch mit austretendem Preßluftstrahl im Überschall an einem Modell nach der Schwingungsmethode gemacht, bei dem die Preßluftzuführung mittels Labyrinthdichtung durch die Drehachse stattfand. Bei den durch die geringe Größe des Modells bedingten experimentellen Schwierigkeiten kommt diesem Versuch nur qualitative Bedeutung zu. Dabei wurde keine Veränderung der Ruderwirksamkeit bemerkt. Das würde bedeuten, daß eine Druckpunktsbeeinflussung nicht stattfindet, bezw. daß die Luftruder - im gleichen Maße wie der Druckpunkt nach rückwärts verlegt wird - infolge der Injektorwirkung besser vom freien Luftstrom beaufschlagt werden.

Die aerodynamische Dämpfung jedoch ist - wie auch früher an anderen Strahlmodellen im Unterschall festgestellt - größer mit austretendem Strahl. Als Dämpfungswert am Modell ohne Strahl wurde etwa der Wert c_d = 3 gefunden als Mittel im gesamten Geschwindigkeitsbereich. Überschlägige Versuche mit dem Strahlmodell bei Ma = 2,5 zeigten eine Dämpfungszunahme von etwa 30 %. (Lit. 20).

8) Die Temperatur der Oberfläche beim Fluge mit Überschall

Zur Vervollständigung des Berichtes über die im Unter- und Überschallgeschwindigkeitsbereich durchgeführten Strömungsuntersuchungen sei noch die folgende thermodynamische Untersuchung, die für die Flakrakete Wasserfall bei der WVA durchgeführt wurde, angeführt:

Die Erwärmung der Oberfläche beim Fluge des Körpers, die einmal durch Abbremsung der Luft an Staupunkten, zum anderen Mal durch Reibung an der Oberfläche stattfindet, erzeugt eine Bremstemperatur in der Grenzschicht, die ihre Wärme durch Leitung, Konvektion und Strahlung an das Behäutungsblech abgibt. Die Kenntnis der auftretenden Blechtemperatur ist notwendig, um Material mit der entsprechenden Warmfestigkeit zu wählen. Die grundlegenden Untersuchungen, die früher für das Aggregat A 4 durchgeführt wurden (Lit. 29), konnten jetzt auch auf die Flakrakete angewandt werden.

Die Temperaturerhöhung des Blechs, die auftritt, ist gegeben durch die Energiergleichung $T_B = T_u + cA\frac{w^2}{2gc_p}$, wobei T_u die Umgebungstemperatur, w die Geschwindigkeit, c_p die spezifische Wärme, g die Endbeschleunigung, A das mechanische Wärmeäquivalent bedeuten und c ein Faktor ist, der im Windkanal ermittelt wurde. c_p nimmt im technischen Maßsystem den Wert 1000 an. c ist im Windkanal in Abhängigkeit von der Machschen Zahl gemessen worden. Der Temperaturverlauf in der Grenzschicht ist in Abb. 21 dargestellt. Aus Wärmeübergangsmessungen im Windkanal konnten die Blechtemperaturen ermittelt werden, die ebenfalls in Abb. 21 in Abhängigkeit von der Flugzeit dargestellt sind.

Bei den auftretenden hohen Temperaturen war es notwendig, festzustellen, wie weit der in der Spitze liegende Sprengstoff vor dem Wärmeeinmarsch geschützt werden konnte. Weiterhin war für eine Glasspitze des Gerätes, die einem Zielsuchgerät diente, bezw. für einen optischen Zünder gedacht war, der Wärmeeinmarsch durch die Glasschicht zu berechnen. Die Untersuchungen sind im Bericht (Lit. 8) niedergelegt.

9) Literaturverzeichnis.

Lfd. Nr.	Archiv-Nr. und Datum	Titel	Verfasser
1)	Heft 1059/43 gK. vom 4. .1943	Schriften der Akademie für Luftfahrtforschung: Geschosse ohne Drall.	Dr. Kurzweg 2. Vortrag
2)	HAP 66/97 gK. vom 27.10.1942	Grundsätzliche aerodynamische Untersuchungen zur Entwicklung der Pee-der Pfeilgeschosse.	Dr. Kurzweg
3)	HAP 66/47 g. vom 11.2.1942	Grundsätzliches über Druckverteilungsmessungen mittels Anbohrungen bei Überschallgeschwindigkeit.	Dipl.-Ing. Erdmann
4)	HAP 66/93 offen vom 24.6.1943	Zur Durchführung von Dreikomponentenmessungen im Pee.-der Überschallwindkanal.	Dipl.-Ing. Kretschmer
5)	HAP 66/100 gK. vom 27.11.1942	Druckverteilungsmessungen am A4 V1P im Bereich der Unter- und Überschallgeschwindigkeiten.	Dipl.Ing. Erdmann
6)	HAP 66/114 gK. vom 6.4.1943	Kurzbericht über erste Dreikomponentenmessungen an der Flakrakete C2/K1/L1/F1/R1.	E.Herrmann
7)	HAP 66/115 gK. vom 23.6.1943	Zusammenfassender Bericht über Dreikomponentenmessungen an fünf verschiedenen Formen der Flakrakete C2.	E.Herrmann
8)	HAP 66/116 gK. vom 15.7.1943	Ultrarotstrahlung der Granzschicht am bewegten Wasserfall-Aggregat	Dr. Kraus Prof. Jordan
9)	HAP 66/117 gK. vom 13.5.1943	Berechnung für die Luftrudersteuerung der Flakrakete C2.	Dipl.-Ing. Erdmann
10)	HAP 66/123 gK. vom 14.7.1943	Dreikomponentenmessungen an einer aerodynamisch verbesserten Form der Flakrakete C2.	E.Herrmann

Lfd. Nr.	Archiv-Nr. und Datum	Titel	Verfasser
11)	HAP 66/125 gK. vom 20.9.1943	Ultrarotstrahlung der Grenzschicht am bewegten Wasserfall-Aggregat. Nachtr. 66/116	Dr. Kraus Prof. Jordan
12)	HAP 66/133 gK. vom 20.12.1943	Windkanaluntersuchungen über den Geschwindigkeits- und Schwerpunktseinfluß auf die Steuerbarkeit des Gerätes C2/E2 des Projekts "Wasserfall".	Dr. Wegener
13)	HAP 66/134 gK. vom 25.2.1944	Vorläufiger Bericht über die Messungen der Scharniermomente an Luftrudern für Projekt „Wasserfall".	Dipl.-Ing. Eckert
14)	HAP 66/136 gK. vom 13.12.1943	Druckverteilungsmessung am C2/K4/L4/F15/R3/0° des Projekts „Wasserfall" bei Ma = 1,87.	Dipl.-Ing. Erdmann E.Herrmann
15)	HAP 66/138 gK. vom 27.2.1944	Weiterer zusammenfassender Bericht über Dreikomponentenmessungen und Nullmomentenmessungen. Messungen an weiteren 17 Formen des Projekts „Wasserfall".	Dipl.-Ing. Raffel
16)	HAP 66/143 gK. vom 3.3.1944	Ergänzungsbericht zu 66/133: (s. lfd. Nr. 12)	Dr. Wegener
17)	HAP 66/144 gK. vom 24.2.1944	Schwingungsmessungen im Windkanal am Gerät C2/E2 und einer verwandten Form des Projekts „Wasserfall".	Dr. Wegener
18)	HAP 66/145 gK. vom 2.3.1944	Windkanaluntersuchungen über die Drallaussteuerung am Gerät C2/E2 des Projekts „Wasserfall".	Dr. Wegener
19)	HAP 66/146 gK. vom 13.3.1944	Vorläufiges Ergebnis der Druckverteilungsmessung am C2/K4/L4/F15/R3/0° des Projekts „Wasserfall" bei Ma = 0,60, 0,84, 1,56, 1,86, 2,50.	Dipl.-Ing. Erdmann E.Herrmann
20)	HAP 66/149 gK. vom 3.8.1944	Vorläufige Ergebnisse aus Schwingungsmessungen im Windkanal am Strahlmodell des Geräts C2/E2a.	Dr. Wegener

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Lfd. Nr.	Archiv-Nr. und Datum	Titel	Verfasser
21)	WVA 150 g. vom 16.9.1944	Über Aufnahme und Auswertung von Oszillogrammen schwingender Modellkörper im Windkanal.	Dr. Wegener
22)	WVA 152 gK. vom 6.12.1944	Messung der Druckverteilung an einem schwenkbaren Ruder für Projekt „Wasserfall" (R 12).	Dipl.-Ing. Eckert
23)	WVA 153 gK. vom 31.10.1944	Vorläufige Ergebnisse der Wind- Windkanalentwicklung von Rudern mit Hilfsrudern zur Steuerung des Geräts „Wasserfall".	Dr. Wegener
24)	WVA 159 gK. vom 1.12.1944	Scharniermomenten- und Steuerbarkeitsmessungen mit dem „Wasserfall"-Ruder 21.	Dipl.-Ing. Eckert
25)	WVA 165 gK. vom 20.3.1945	Ruderentwicklung im Windkanal zur Raketensteuerung im Unter- und Überschall.	Dr. Wegener Dipl.-Ing. Eckert
26)	WVA 166 gK. vom 3.3.1945	Zum S-Schlag der Steuerbarkeitskurven des Geräts „Wasserfall".	Dr. Wegener
27)	WVA 137 in Vorbereitung	Die Nullmomenten-Meßmethode.	Dipl.Ing. Kretschmer
28)	TH Darmstadt	Berichte über Schwingungen des Aggregates um seinen Schwerpunkt: 5., 11., 13., 14. und 15. Bericht.	Dr. Schneller
29)	WVA 57 g. vom 21.11.1941	Experimentelle Untersuchung der Bremstemperatur und des Wärmeübergangs an einfachen Körpern bei Überschallgeschwindigkeit.	Dr. Eber (Diss.)
30)	vom 17.12.1943	Patentschrift: Tandemanordnung von Trag- und Leitwerk.	Dr. Kurzweg

Definitionen und Bezeichnungen.

C2 = Wasserfall E = Einsatzgerät, Nr. zur Unterscheidung

K = Körper (auch Index) R = Ruder (auch Index)

D = Kaliber $F = \frac{\pi}{4} D^2$ = Kaliberfläche L = Länge

S/D = Abstand des Geräteschwerpunktes in Kalibern von Düsenhinterkante

H/D = Abstand des Luftangriffspunktes in Kalibern von Düsenhinterkante

$S/D - H/D = \frac{p_K}{D}$ = Luftkrafthebelarm des Gesamtaggregats

$\frac{S_R}{D}$ = Abstand der Ruderdrehachse in Kalibern von Rudervorderkante

$\frac{p_R}{D}$ = Luftkrafthebelarm des Ruders

α = Körperanstellwinkel, Winkel zwischen Anströmrichtung u. Geschoßlängsachse, positiv bei Neigung der Spitze unter die Anströmrichtung

η = Ruderausschlag gegen das Leitwerk gemessen, positiv bei Auslenkung der Ruderhinterkante über die Geschoßlängsachse.

φ = Querneigungswinkel $\Delta \varphi$ = Winkel zwischen Flügel u. Leitwerksebene

δ = Schränkwinkel einzelner Flächen gegen Geschoßlängsachse

$Ma = \frac{w}{a} = \frac{\text{Fluggeschwindigkeit (Anströmgeschwindigkeit)}}{\text{örtliche Schallgeschwindigkeit}}$

ϱ = Luftdichte $q = \frac{\varrho}{2} w^2$ = Staudruck

A = Auftrieb, W = Widerstand, N = Normalkraft, M = Moment

N_R = Rudernormalkraft, M_R = Ruderscharniermoment, M_l = Drallmoment

R = Dämpfungszahl

$c_a = \frac{A}{q \cdot F}$ = dimensionsloser Auftriebsbeiwert, $c_w = \frac{W}{q \cdot F}$ = dimensionsloser Widerstandsbeiwert

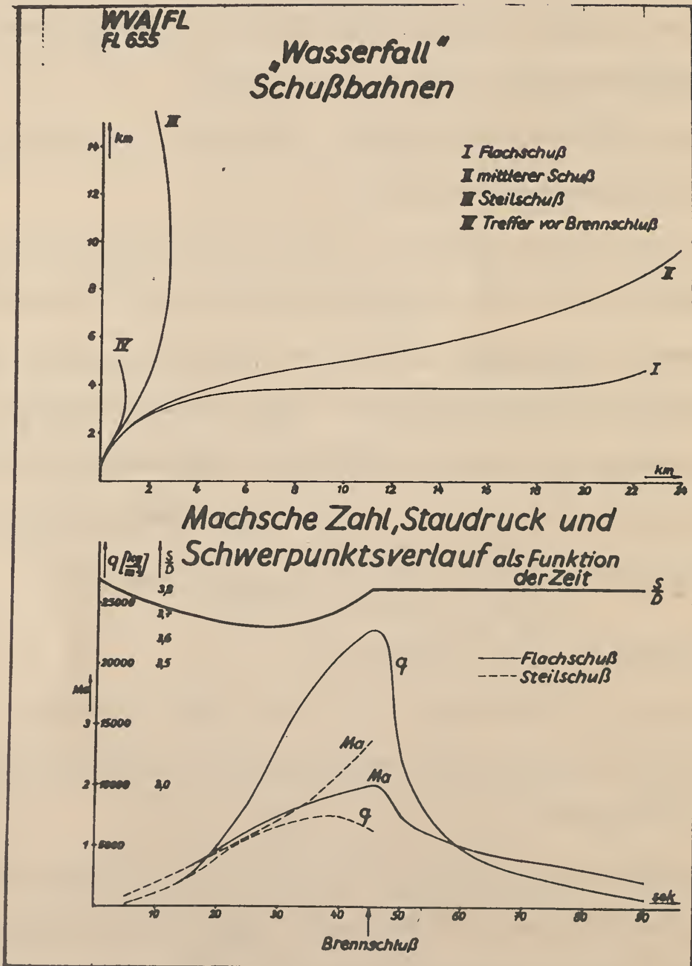
$c_n = \frac{N}{q \cdot F}$ = dimensionsloser Normalkraftsbeiwert, $c_m = \frac{M}{q \cdot F \cdot D}$ = dimensionsloser Momentenbeiwert

$c_l = \frac{M_l}{q \cdot F \cdot D}$ = dimensionsloser Drallmomentenbeiwert, $c_d = \frac{24 R}{L^3 \cdot D \cdot \varrho \cdot w}$ = dimensionsloser Dämpfungsbeiwert

$c_R = \frac{M_R}{q \cdot F \cdot D}$ = dimensionsloser Ruderscharniermomentenbeiwert

$\varepsilon = \frac{c_a}{c_w}$ = Gleitzahl $n = \frac{A}{G}$ = Lastvielfaches = $\frac{\text{Auftrieb}}{\text{Gewicht}}$

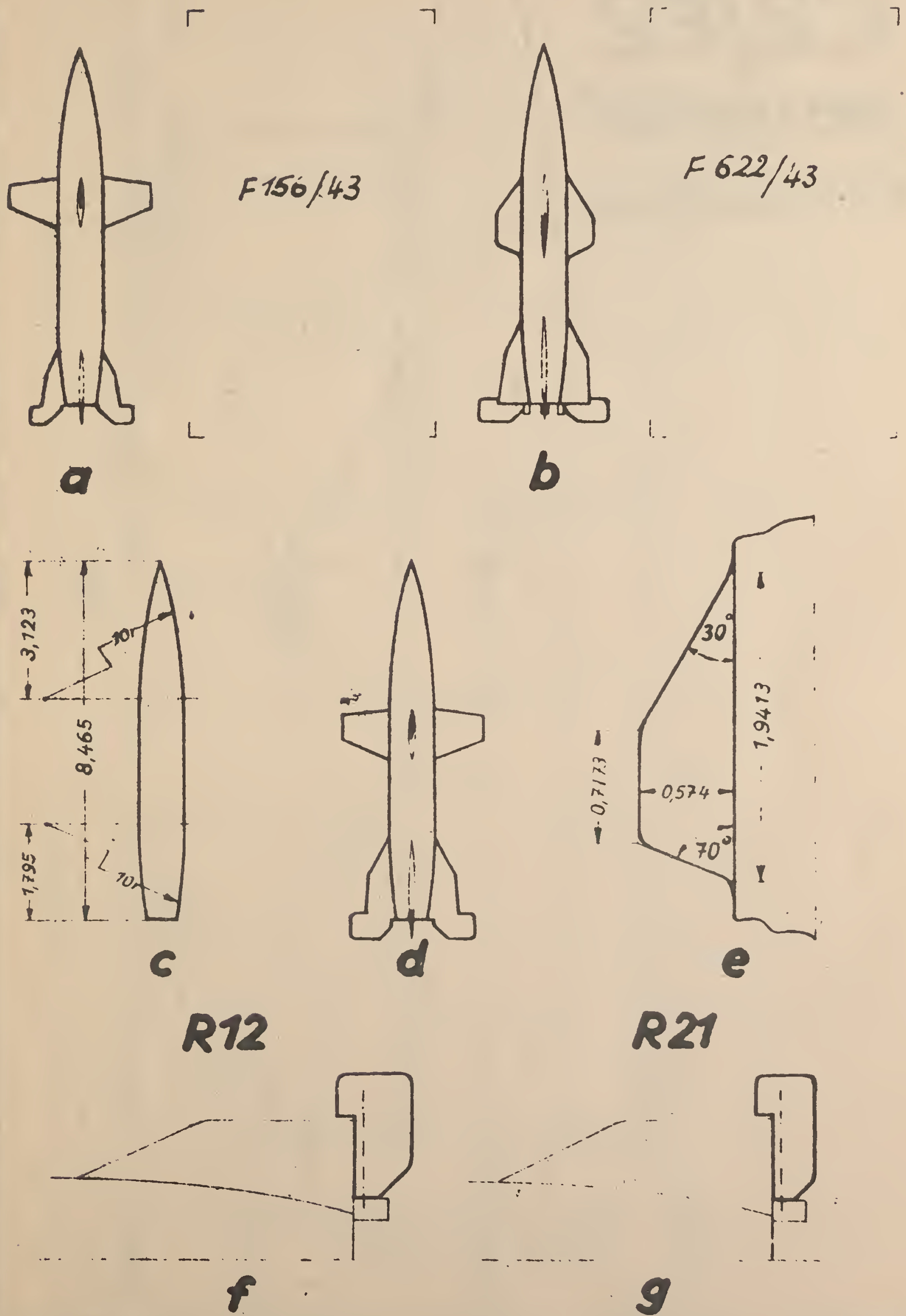
Abb. 1


WVA/FL
FL 655
„Wasserfall"
Schußbahnen
km
I Flachschuß
II mittlerer Schuß
III Steilschuß
IV Treffer vor Brennschluß
I
II
III
IV
2
4
6
8
10
12
14
16
18
20
22
24
km
Machsche Zahl, Staudruck und
Schwerpunktsverlauf als Funktion
der Zeit
q
Ma
S/D
25000
20000
15000
10000
5000
3,8
3,7
3,6
3,5
3,0
1
2
3
Flachschuß
Steilschuß
10
20
30
40
50
60
70
80
90
sek
Brennschluß

WVA/FL Archiv Nr. 171 g Kdos

Abb.2

„Wasserfallentwicklung"



gepr.: 20.2.45 Meier

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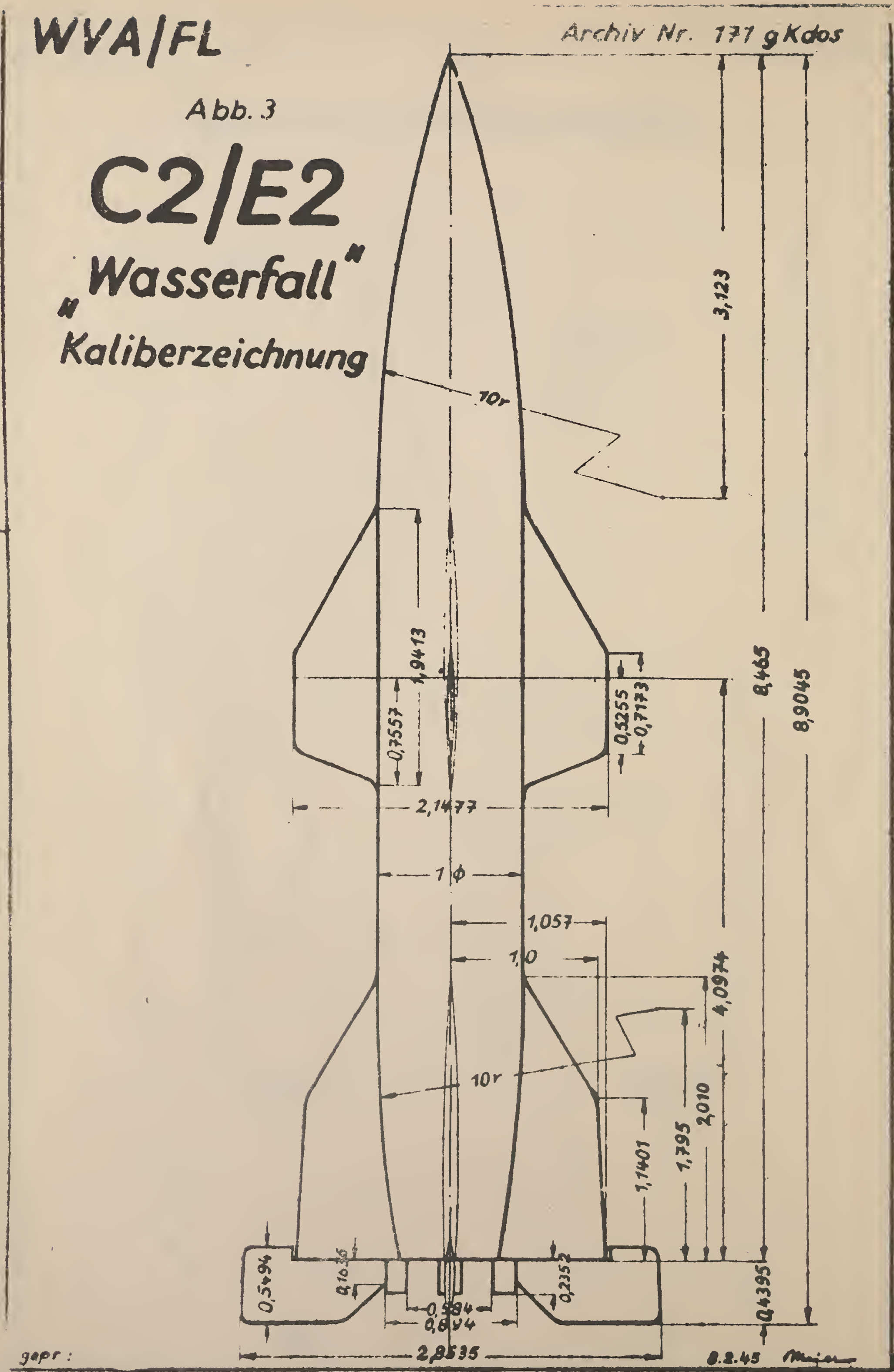


WVA/FL
Archiv Nr. 171 g Kdos
Abb. 3
C2/E2
„Wasserfall"
Kaliberzeichnung
3,123
10r
1,9413
0,7557
0,5255
0,7173
8,465
8,9045
2,1477
1 ϕ
1,057
1,0
4,0974
10r
2,010
1,795
1,1401
0,5494
0,1635
0,2352
0,4395
0,584
0,894
2,8535
gepr:
8.2.45

Abb. 4

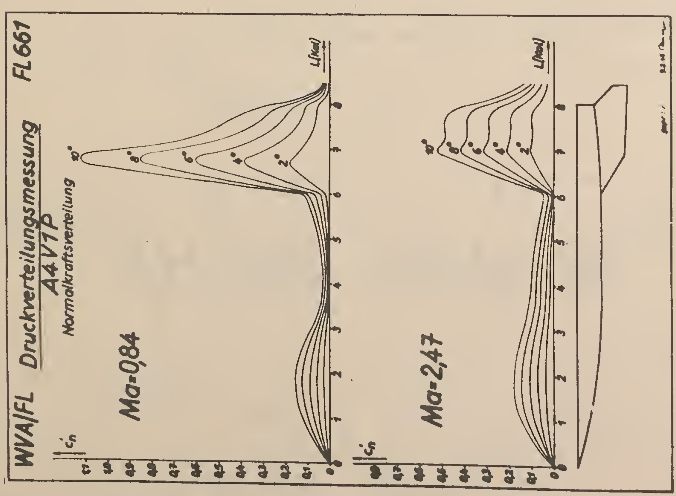
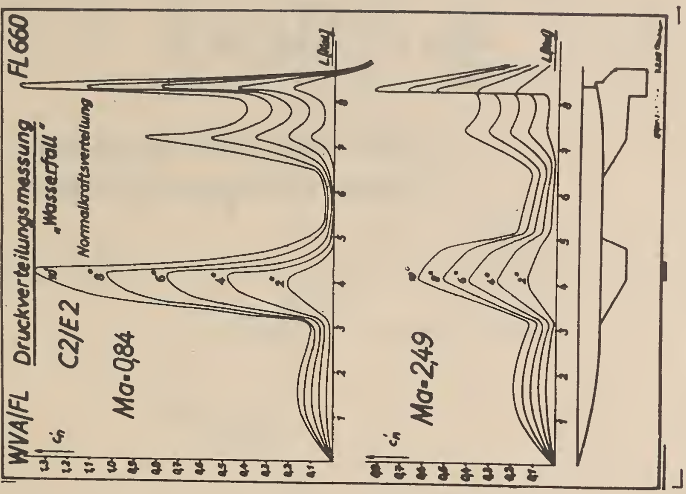
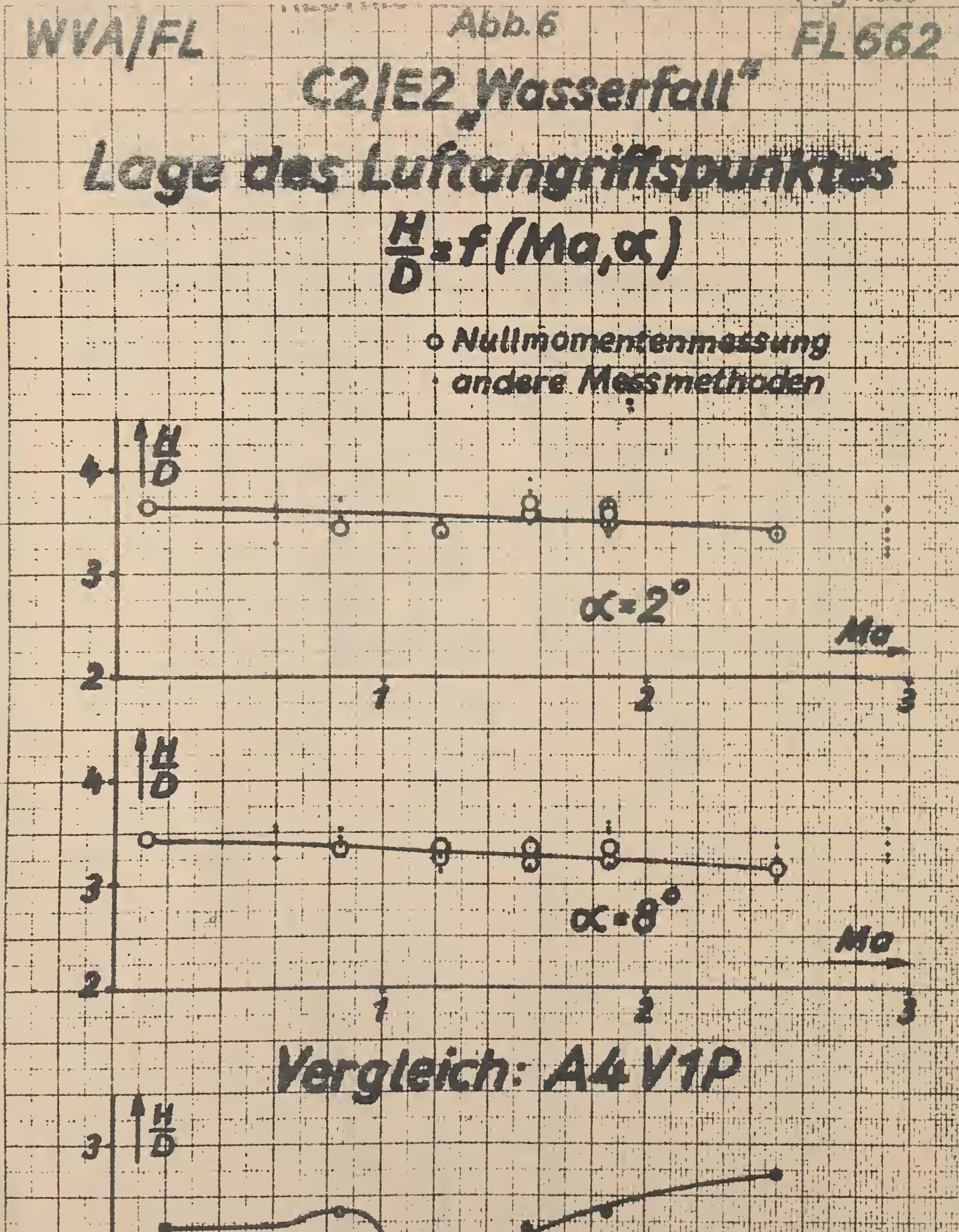

WVA/FL Druckverteilungsmessung A4 V1 P FL 661
Normalkraftsverteilung
Ma=0,84
Ma=2,47
L (Kal)

Abb. 5


WVA/FL Druckverteilungsmessung „Wasserfall" FL 660
C2/E2
Normalkraftsverteilung
Ma=0,84
Ma=2,49
L (Kal)


WVA/FL
Abb. 6
FL 662
C2/E2 „Wasserfall"
Lage des Luftangriffspunktes
H/D = f (Ma, α)
o Nullmomentenmessung
· andere Messmethoden
H/D
α = 2°
Ma
α = 8°
Vergleich: A4 V1P
gepr.:

WVA/FL FL 667

Scharniermomente der „Wasserfall"-Ruder 12 u. 21

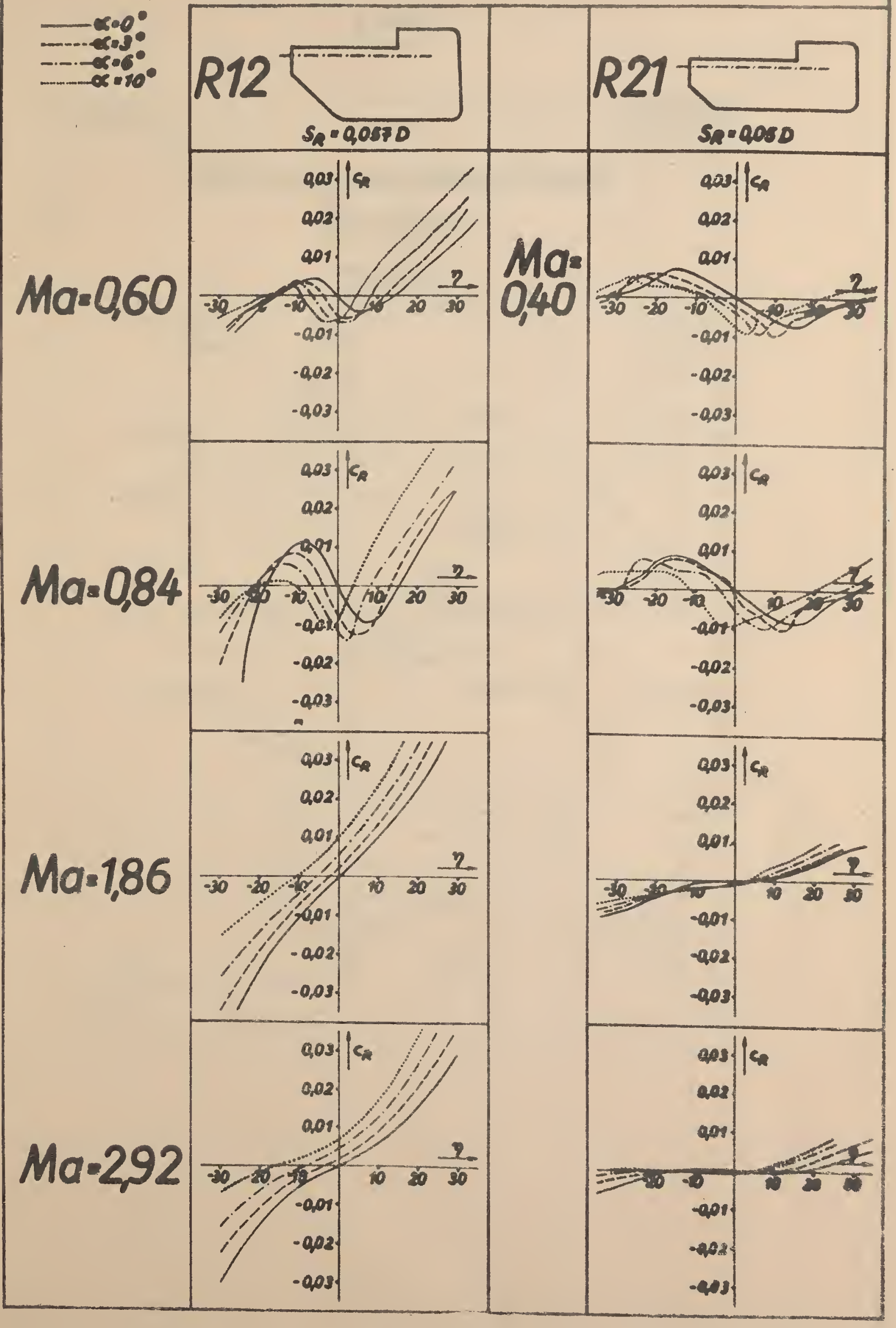


Abb. 8

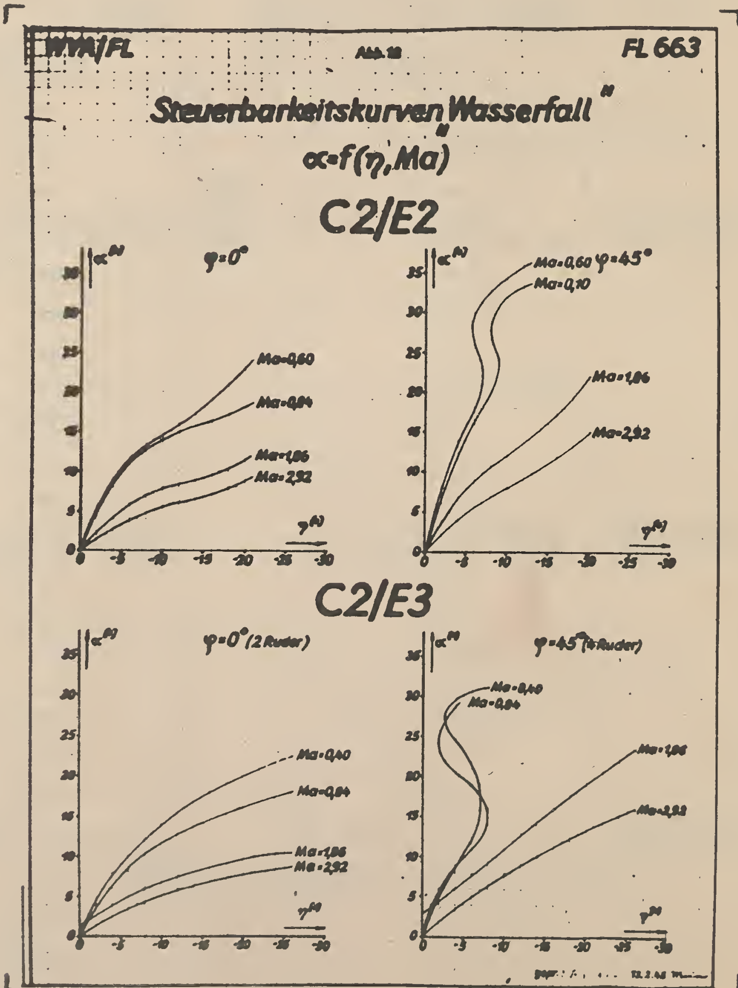

WVA/FL
FL 663
Steuerbarkeitskurven „Wasserfall“
α=f(η, Ma)
C2/E2
φ=0°
Ma=0,60
Ma=0,84
Ma=1,86
Ma=2,92
Ma=0,60 φ=45°
Ma=0,10
Ma=1,86
Ma=2,92
C2/E3
φ=0° (2 Ruder)
Ma=0,60
Ma=0,84
Ma=1,86
Ma=2,92
Ma=0,60
Ma=0,84
Ma=1,86
Ma=2,92

Abb. 9

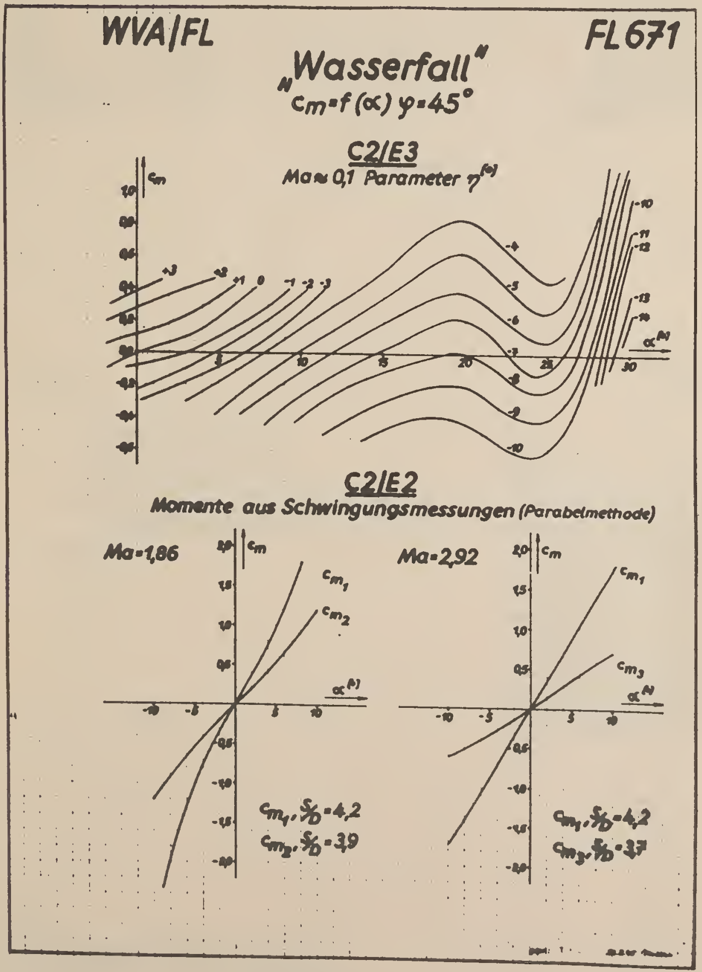

WVA/FL
FL 671
„Wasserfall"
cm=f(α) φ=45°
C2/E3
Ma≈0,1 Parameter η°
C2/E2
Momente aus Schwingungsmessungen (Parabelmethode)
Ma=1,86
Ma=2,92
cm1, S/D=4,2
cm2, S/D=3,9
cm1, S/D=4,2
cm3, S/D=3,7

Abb. 10

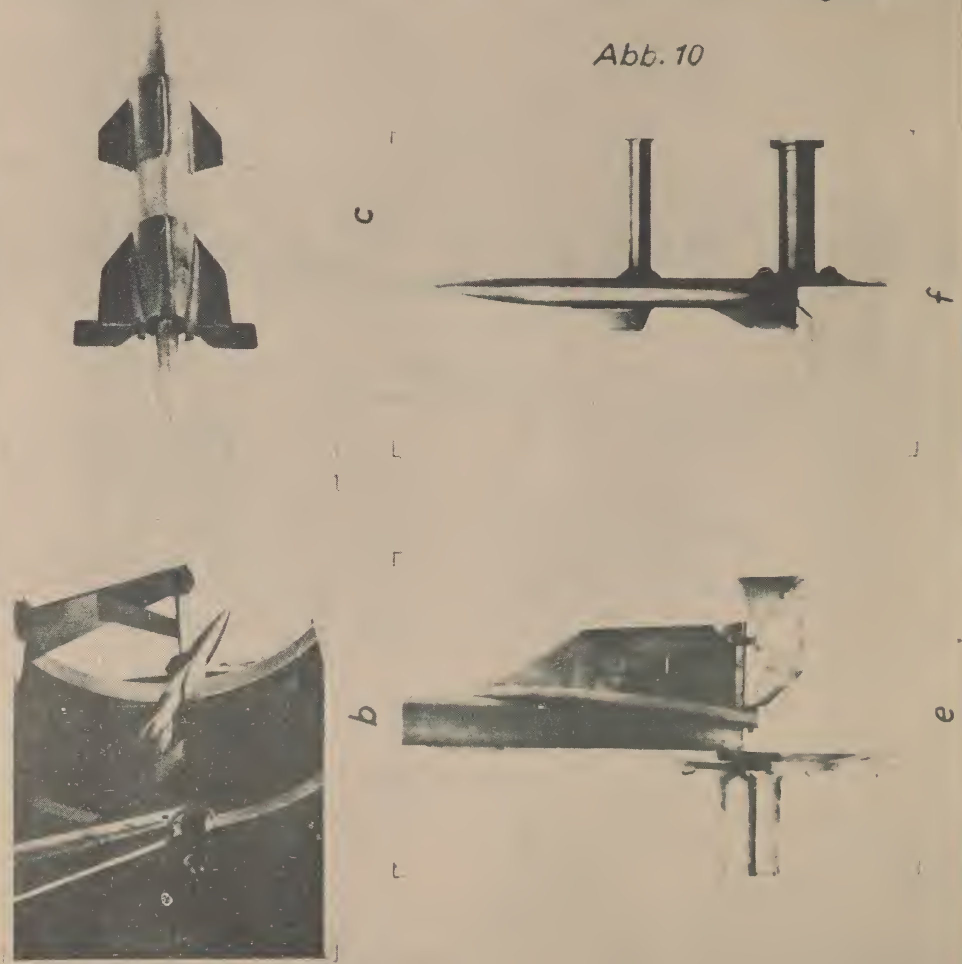


Abb. 11

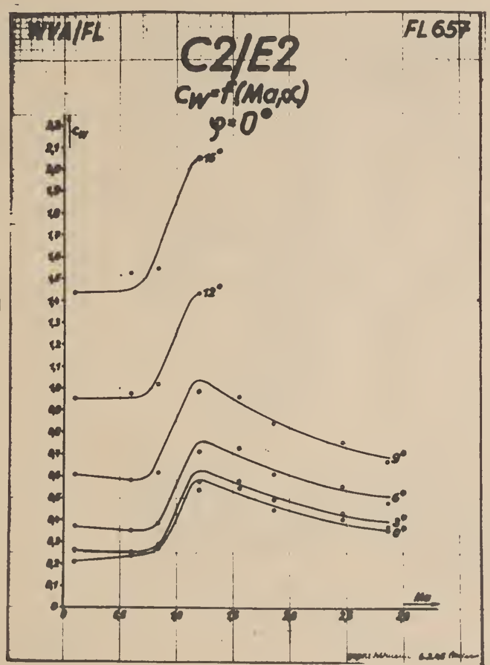


Abb. 12

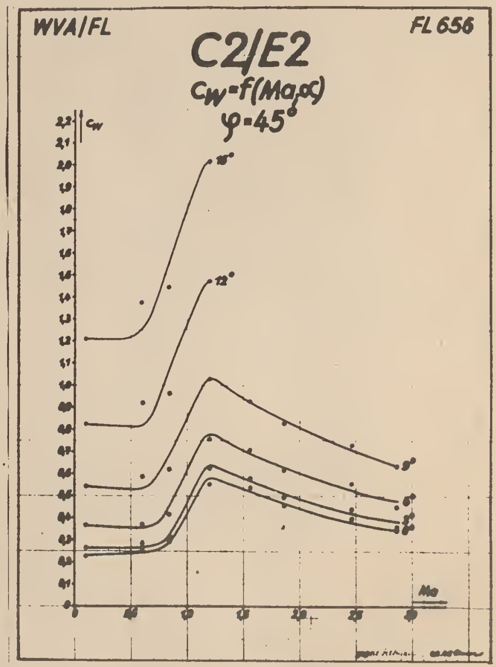


Abb. 13

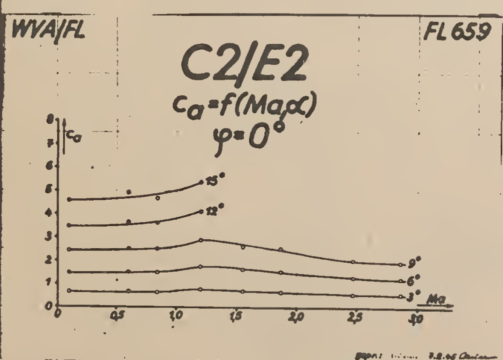
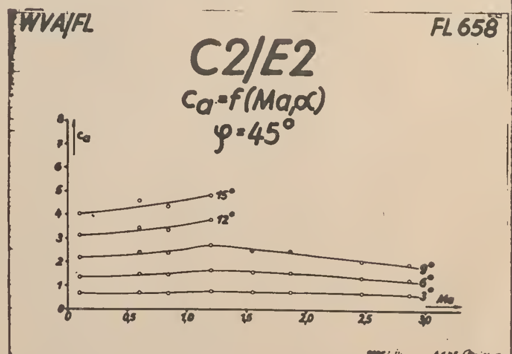


Abb. 14



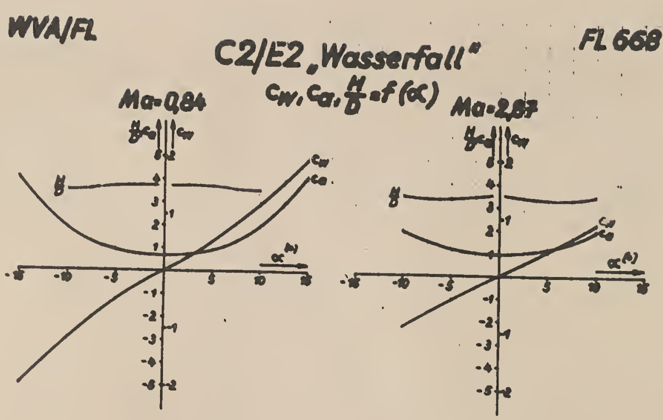


Abb.15

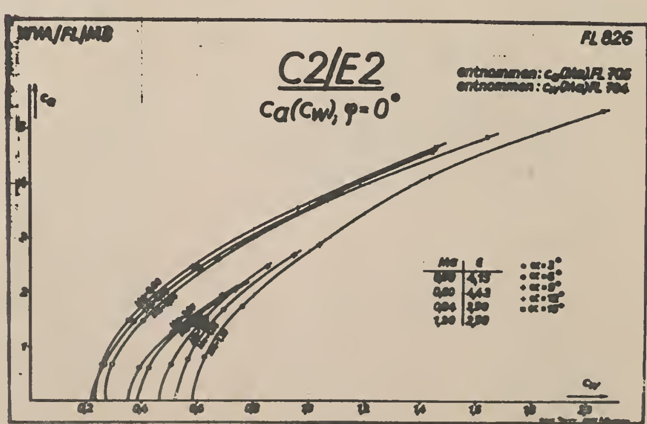


Abb.16

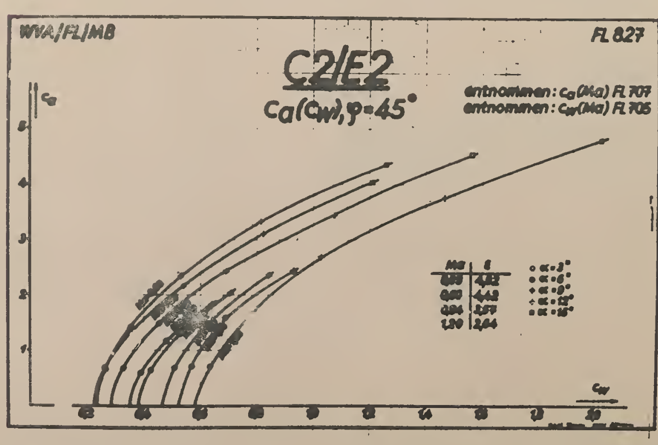


Abb.17

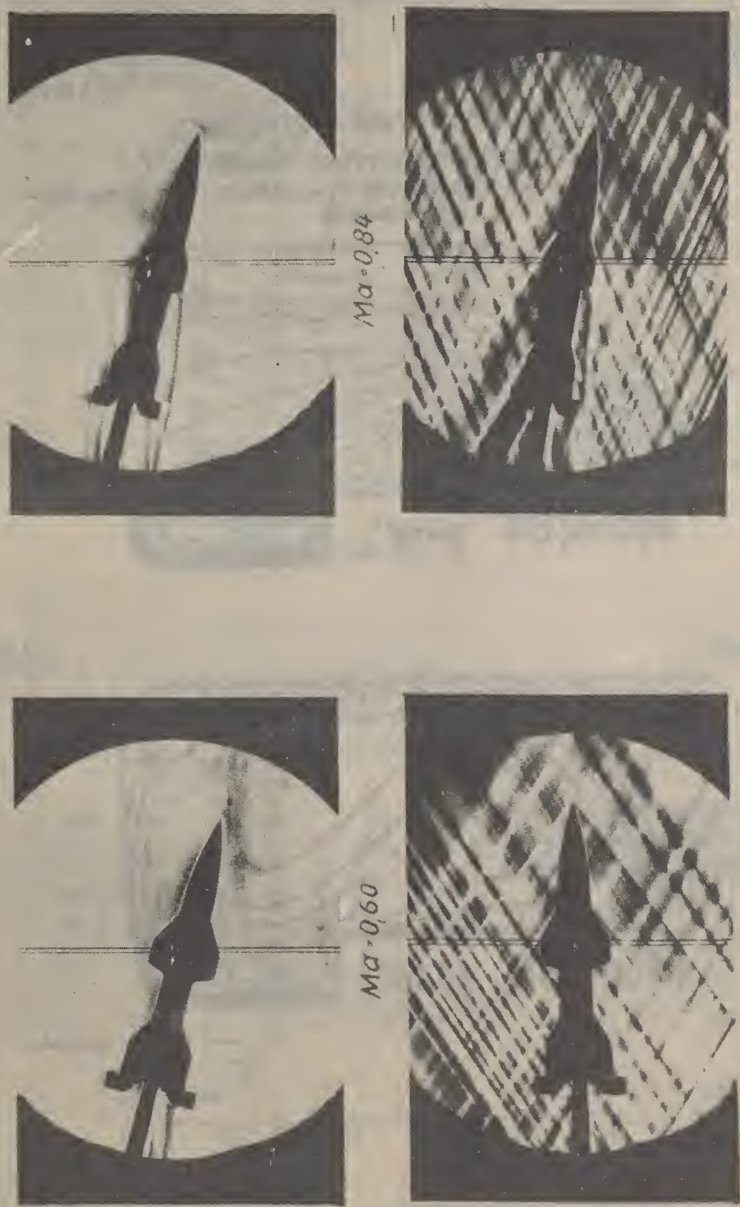


Abb.18

Abb. 19

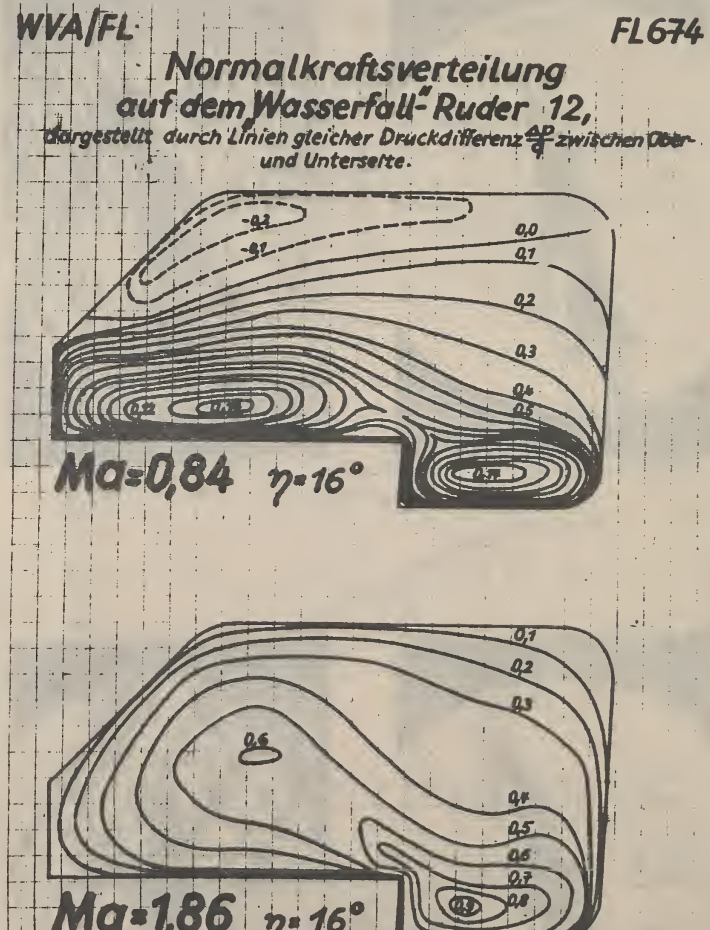

WVA/FL
FL 674
Normalkraftsverteilung
auf dem „Wasserfall" Ruder 12,
dargestellt durch Linien gleicher Druckdifferenz Δp/q zwischen Ober- und Unterseite.
0,0
0,1
0,2
0,3
0,4
0,5
Ma=0,84 η=16°
0,1
0,2
0,3
0,6
0,4
0,5
0,6
0,7
0,8
Ma=1,86 η=16°

Abb.20

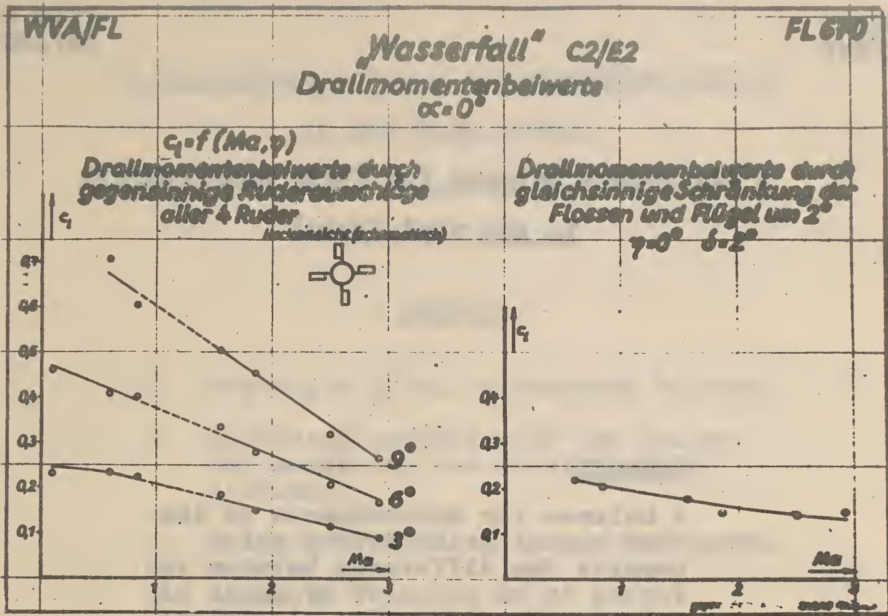
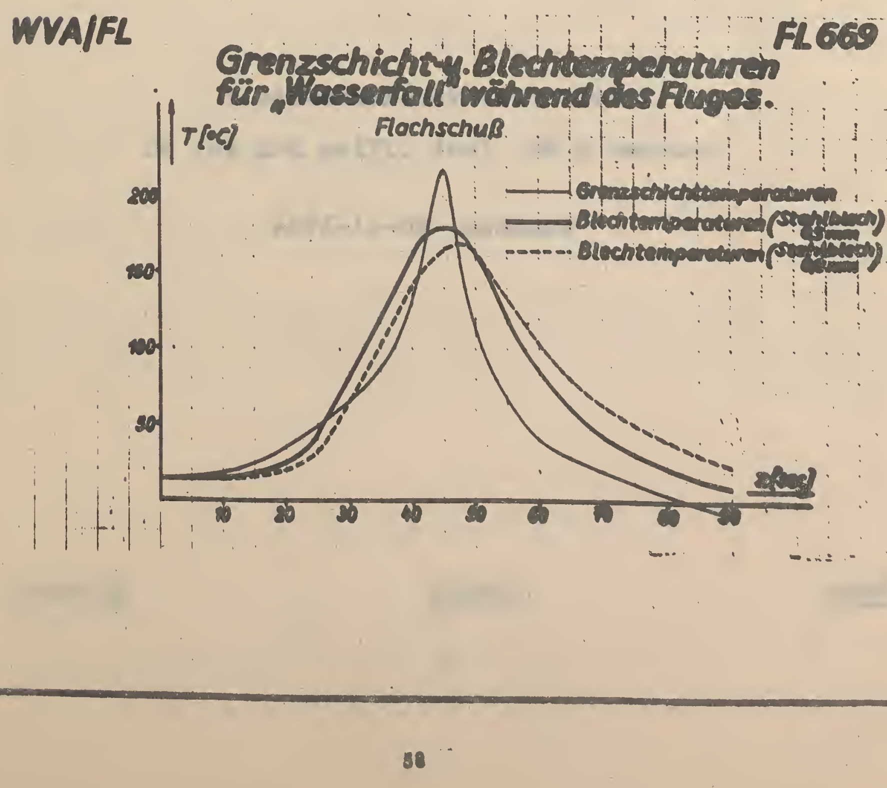

WVA/FL
FL 670
„Wasserfall" C2/E2
Drallmomentenbeiwerte
α=0°
$c_l = f(Ma, \eta)$
Drallmomentenbeiwerte durch gegensinnige Ruderausschläge aller 4 Ruder
Drallmomentenbeiwerte durch gleichsinnige Schränkung der Flossen und Flügel um 2°
η=0° δ=2°
9°
6°
3°
Ma

Abb.21


WVA/FL
FL 669
Grenzschicht-u. Blechtemperaturen für „Wasserfall" während des Fluges.
Flachschuß
T [°C]
Grenzschichttemperaturen
Blechtemperaturen
Blechtemperaturen
z [sec]

WVA
E/EMP

File No.
66/158

A difference balance for force measurements in the wind tunnel

Summary:

A balance for measurements in the wind tunnel is described which permits the difference between two forces to be measured by means of a bridge for measuring electrical resistance.

Wasserbau-Versuchsanstalt

Munchen 2 BS, Post Office Box No. 60

Munchen, 28-11-1944

Ramm Arnold Hermann

A difference balance for measuring forces in the wind tunnel

Summary

1. Principle of the difference balance.
2. Adjusting condition of the bridge for measuring the electrical resistance.
3. Execution of tests and measurements.
4. Summary.

The report 66/142 (on the use of electro-magnetic systems of pressure measuring boxes as the means of measuring in the balance) showed briefly the suitability of the electro-magnetic systems of pressure measuring boxes for measurements of force. In particular, the system of the E Box with a laminated Mu-Metal-Core (Topfkern) acts very well in respect of the straightness of the gauge curve, the sensitivity and the independence of the temperature. The sensitivity can be increased by using the second box also as a measuring box in the bridge.

1) Principle of the difference balance.

The present measuring practice in the wind tunnel gives two measurements (main and diaphragm measurements) the difference of which then gives the true forces on the model under examination. This measurement becomes more inaccurate the smaller the difference between the main and diaphragm measurement in a given measuring accuracy.

If the main measurement H and the diaphragm measurement B are measured with a percentage inaccuracy of p %, the deviation amounts to $\frac{H.p}{100}$ or $\frac{B.p}{100}$. The percentage error of the difference H - B becomes:

$$\frac{100\left(\frac{H.p}{100} + \frac{B.p}{100}\right)}{H - B}\,\% \quad \text{or} \quad \frac{p(H + B)}{H - B}\,\%$$

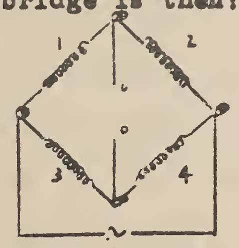
In order to evaluate this, let the main measurement show a deflection of 100 Skt and the diaphragm measurement of 90 Skt measured with an accuracy of 2%. The measuring accuracy of the difference H - B = 10 is then $\frac{2 \cdot 190}{10}\,\% = 38\%$. The measuring error of the difference increases thus by these probable figures throughout up to approximately 20 times the amount.

This led to the idea of finding the difference electrically in the resistance bridge. For this purpose, it is necessary to have available, for the measuring of one component, two spring systems, one of which measures the forces at the segment and holder, while the other measures the total force. Consequently, the segment and model holder must consist of two equal parts in respect of the aerodynamic behavior, so that the forces at these parts are equal during the blowing process. To be more independent of the size of the resultant forward load, both springs must possess exactly the same characteristics.

2) <u>Adjusting conditions of the resistance bridge.</u>

As it was necessary to synchronize the bridge quickly with the simplest and least possible handling, tests were made to find out which influence made an alteration of the links of the bridge.

Each spring was provided with two boxes to increase the sensitivity (compare report 66/142 p. 4). The box system of the second spring acts in the bridge resistance in the opposite sense. In each of the four branches of the bridge lies an inductance core L with a fixed Ohm resistance portion R. The condition for the absence of tension in the branch of the bridge is then:



$$(R_1 + jwL_1)\ (R_4 + jwL_4) = (R_2 + jwL_2)\ (R_3 + jwL_3)$$

As a standard for desynchronizing the bridge, the size of the bridge determinant serves which in the case in question is:

$$D = (R_2 + jwL_2)(R_3 + jwL_3) - (R_1 + jwL_1)(R_4 + jwL_4)$$

$$= R_2R_3 - R_1R_4 - w^2(L_2L_3 - L_1L_4)$$
$$+ jw(R_3L_2 \quad R_2L_3 - R_4L_1 - R_1L_4)$$

$$= A + jB$$

The determinant can be divided into an actual portion

$$A = R_2R_3 - R_1R_4 - w^2(L_2L_3 - L_1L_4)$$

and an imaginary portion:

$$B = w(R_3L_2 + R_2L_3 - R_4L_1 - R_1L_4)$$

The size of the bridge determinant then gives in the A;jB level the distance from the beginning point of the coordinate and is thus the standard for the desynchronization. The bridge is then synchronized if the bridge determinant is zero.

The condition of adjustment can be fulfilled by a variable bridge link. The locus curve in the AjB level best reproduces the influence of this variable in the bridge condition. The most simple are the changeable contact resistances. The locus curve for changeable R is, for example, a straight line with the axis section.

$$a = R_2 R_3 - \frac{R_4}{L_4}\left(R_3L_2 + R_2L_3 - R_4L_1\right) - \omega^2\left(L_2L_3 - L_1L_4\right)$$

at the A axis and

$$b = \omega\left\{R_3L_2 + R_2L_3 - R_4L_1 - \frac{L_4}{R_4}\left[R_2R_3 - \omega^2\left(L_2L_3 - L_1L_4\right)\right]\right\}$$

at the jB axis. The inclination of this straight line is then:

$$\operatorname{tg}\alpha_{R_1} = \frac{b}{a} = \frac{\omega\left\{R_3L_2 + R_2L_3 - R_4L_1 - \frac{L_4}{R_4}\left[R_2R_3 - \omega^2\left(L_2L_3 - L_1L_4\right)\right]\right\}}{R_2R_3 - \frac{R_4}{L_4}\left(R_3L_2 + R_2L_3 - R_4L_1\right) - \omega^2\left(L_2L_3 - L_1L_4\right)}$$

The inclination of the appropriate locus curve at the variable R_4 is:

$$\operatorname{tg}\alpha_{R_4} = \frac{\omega\left\{R_3L_2 + R_2L_3 - R_1L_4 - \frac{L_1}{R_1}\left[R_2R_3 - \omega^2\left(L_2L_3 - L_1L_4\right)\right]\right\}}{R_2R_3 - \frac{R_1}{L_1}\left(R_3L_2 + R_2L_3 - R_1L_4\right) - \omega^2\left(L_2L_3 - L_1L_4\right)}$$

As R_1 and R_4, as well as L_1 and L_4 in the foregoing case are not very different. The inclinations of both straight lines do not differ very much from each other.

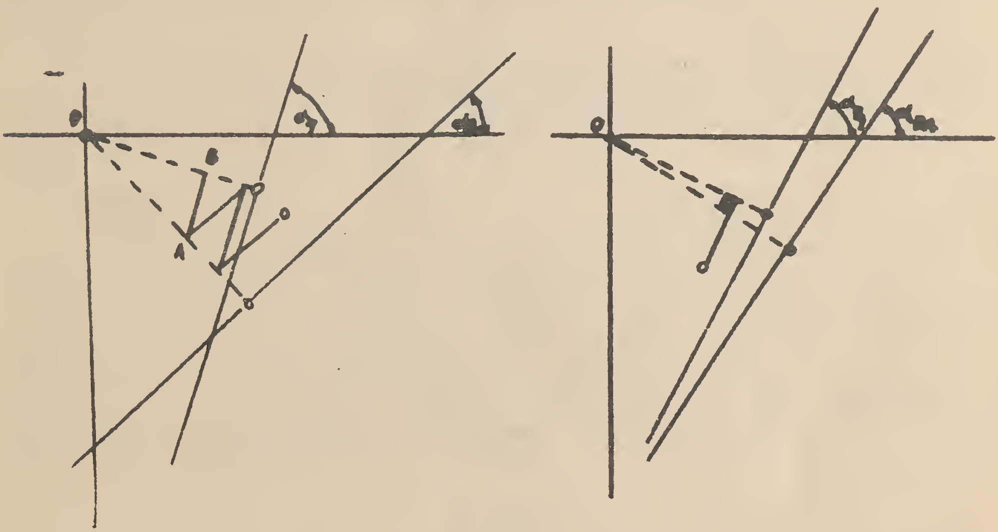
The synchronization of the bridge follows by changing a link of the bridge, i.e. a minimum is sought on the appropriate locus line, which is then apparently reached by finding the nadir of the perpendicular from the beginning of the coordinates at the locus line.

The regulating accuracy depends on the sensitivity of the circuit. Thereupon, with the help of a second changeable circuit, a new minimum is found and so on, and thus successively approaches the final synchronization (bridge determinant D equal to zero). The more often one approaches the beginning of the coordinating point with one step, the quicker the synchronization is brought about.

The standard for the convergence of the bridge synchronization according to Kupfmüller is:

$$k = \log \frac{OA}{OB} = \log \frac{7}{\cos (d_1 - d_2)}$$

Now d_1 d_2, so the convergence is extraordinarily bad. (Plan 2)



If this is made variable in relation to L_1, the locus line cuts out the sections:

$$a = R_2 R_3 - R_1 R_4 - \omega^2 \left[L_2 L_3 - \frac{L_4}{R_4} \left(R_3 L_2 + R_2 L_3 - R_1 L_4 \right) \right]$$

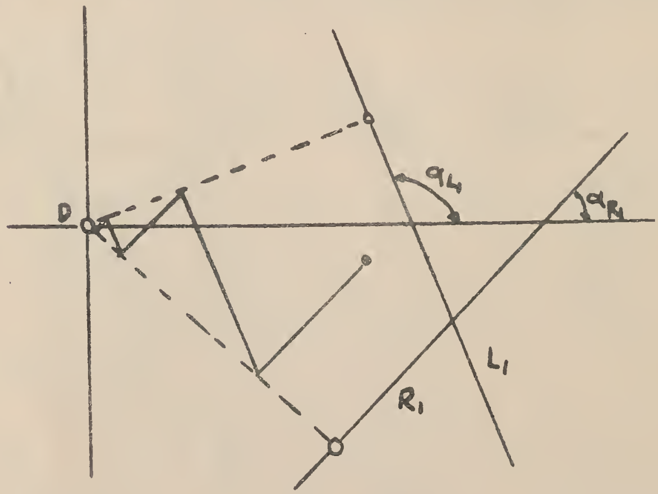
$$b = \omega \left\{ R_3 L_2 + R_2 L_3 - R_1 L_4 - \frac{R_4}{\omega^2 L_4} \left(R_1 R_4 - R_2 R_3 + \omega^2 L_2 L_3 \right) \right\}$$

at the coordinating axis, the inclination becomes

$$tg\alpha_{L_1} = \frac{\omega\left\{R_3L_2 + R_2L_3 - R_1L_4 - \frac{R_4}{\omega^2 L_4}\left(R_1R_4 - R_2R_3 + \omega^2 L_2L_3\right)\right\}}{R_2R_3 - R_1R_4 - \omega^2\left[L_2L_3 - \frac{L_4}{R_4}\left(R_3L_2 + R_2L_3 - R_1L_4\right)\right]}$$

The inclination with the variable l_1 is evidently essentially different from the inclinations of the locus lines with the variable R_1 or R_4. Here, the convergence is better (Sect. 3)

For the circuit in question, k has approximately the value 0.3, i.e. that after approximately 4 adjustments, the current in the bridge diagonal has fallen to the twentieth part of its initial value (4.k   log 20).



3) Execution of tests and measurements.

In practice, the variable L was represented by a small wound up coil, into which an iron screw could be more or less turned. The changeable resistance was as usual a contact wire body. Two stretched plates of the usual kind of iron and measuring 150 x 60 x 10 mm were used in an improvised form as springs. The measurements were checked as accurately as possible for both plates. The deflection of the plates amounted to 0.14 mm under a load of 10 kg. On the front, the weight holders were screwed up. The air chinks of the four boxes were made as accurately equal as possible. As, in spite of this, the bending of the springs was not absolutely equal and small differences occured in the sizes of the chinks, the head screw of the one spring was extended and provided with several wedge shaped nuts, which could be put into the weight holder. By adjusting this screw, a completely equal deflection of the spring can be achieved. There then occurs a small hysteresis of the spring of approximately 2 to 3% by increasing and decreasing the load, which can probably be explained by the stretching of the springs as with the springs in the wind tunnel. By relaxing this attachment, this hysteresis disappears within the maximum measuring range of 10 kg.

Measurements were made with different air chinks and forward loads. As an example, gauge lines were repeated for each box with chinks of 1 and 2 mm. The measuring points were taken without forward load, and at 2 kg and 5 kg. (Plan 4)

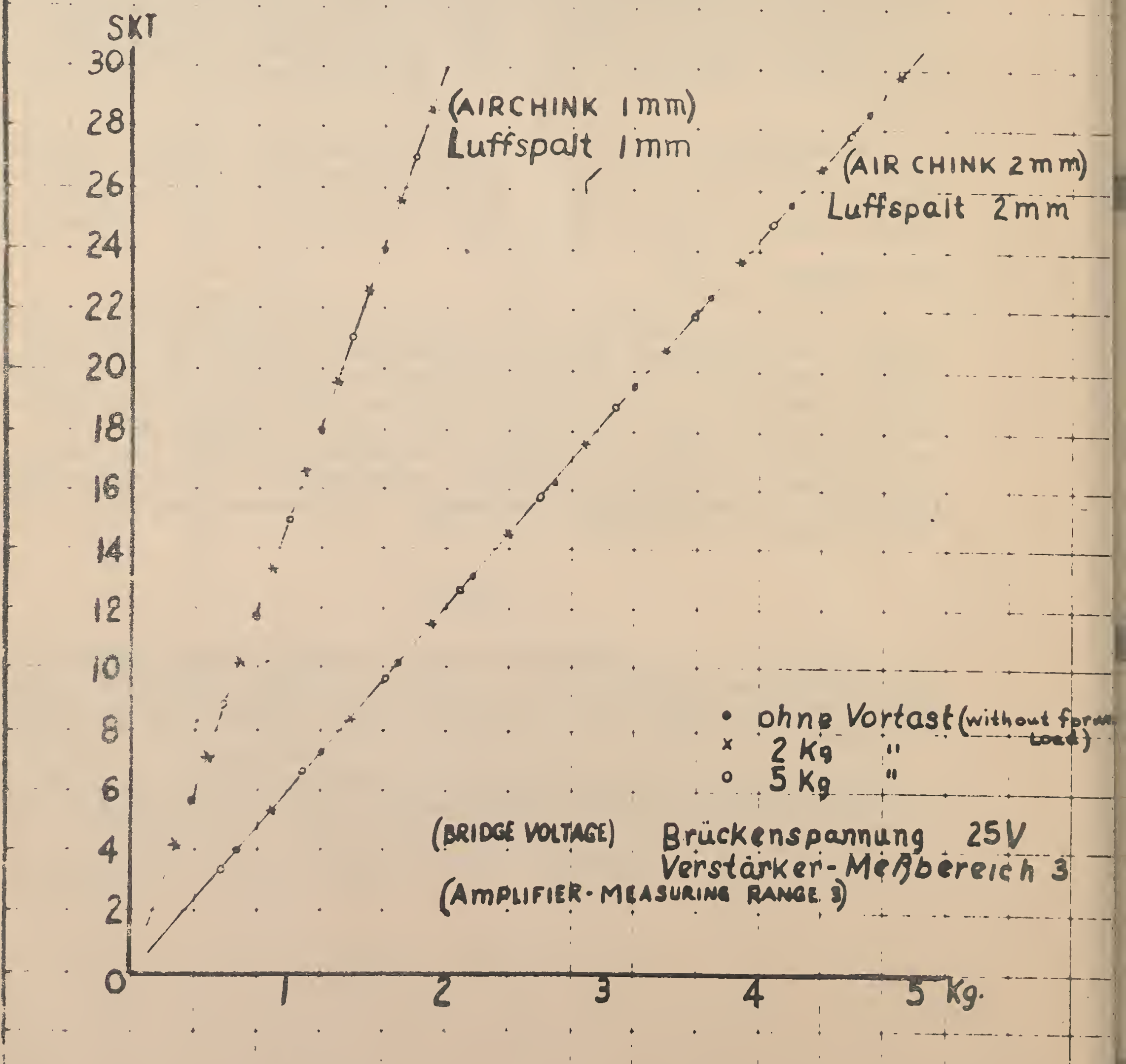
4) Summary.

A balance arrangement for force measurements in the wind tunnel is described, which is designed to build up the difference between main and diaphragm measurements by an electrical method in a resistance bridge. For the determination of the force, only one measurement is thus necessary. As opposed to the former method of separately taking the main measurement H and the diaphragm measurement B, the measuring accuracy is considerably increased. The measuring error of both methods differs by the factor

$$\frac{H + B}{H - B}$$

The conditions of adjustment for a rapid and exact adjustment of the bridge are deduced. A small variable inductivity must still be connected into a branch of the bridge near a variable resistance.

The difference balance has been experimentally tested in two provisional spring arrangements.


SKT
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
(AIRCHINK 1mm)
Luffspalt 1mm
(AIR CHINK 2mm)
Luffspalt 2mm
• ohne Vortast (without fore load)
x 2 Kg "
o 5 Kg "
(BRIDGE VOLTAGE) Brückenspannung 25V
Verstärker-Meßbereich 3
(AMPLIFIER-MEASURING RANGE 3)
1
2
3
4
5 Kg.

CIOS Team of 21 technicians carefully checked the dispersals of various scientists and then took six to England for even further interrogations

Part 1 of 3 parts

6 best taken to London for
further investigation. Very few
of these reports yet available.

Peenemunde East

through the eyes of

500

detained at Garmish

Peenemunde

Management

represented by Lt. Gen. Dornberger

Development

represented by Prof. Werner von Braun

Planning
by Dannenburg

Sub Sections

Statie – Hellebrand

Stability – Bornscheuer – missing reports

A4 Design – Schulz – missing reports

Wasserfall – Patt

Taifun – Dannenburg

Fittings – Mullinger

Fuels – Heller

Mat Res. – Steuer

Electrical Apparatus
by Dr. Steinhoff

Sub Sections

Circuits - Wierer

Control - Muller (2) *

Operation - Brützel *

Prelim Test - Böhn

Test + Trials - Debus

Static Ground Control - Frichtu *

Assembly - Neubert *

The work of Müller II head of controls department and Brützel of operations are covered by Ottenthal (Sharpe), Steinhoff, Lange and others

GROUND EQUIP.

HANS HUTER.

Subsections

Building - Lührsen
Test Building - Tessman
Special Vehicles - Elmer
Transport - v. Liebhaber
Spare Parts -
Constructions - Weintraud

Production
Rees.

<u>Sub-Sections</u>

Control Planning - Kuers
Stores - Schafer
Job Control - de Vries

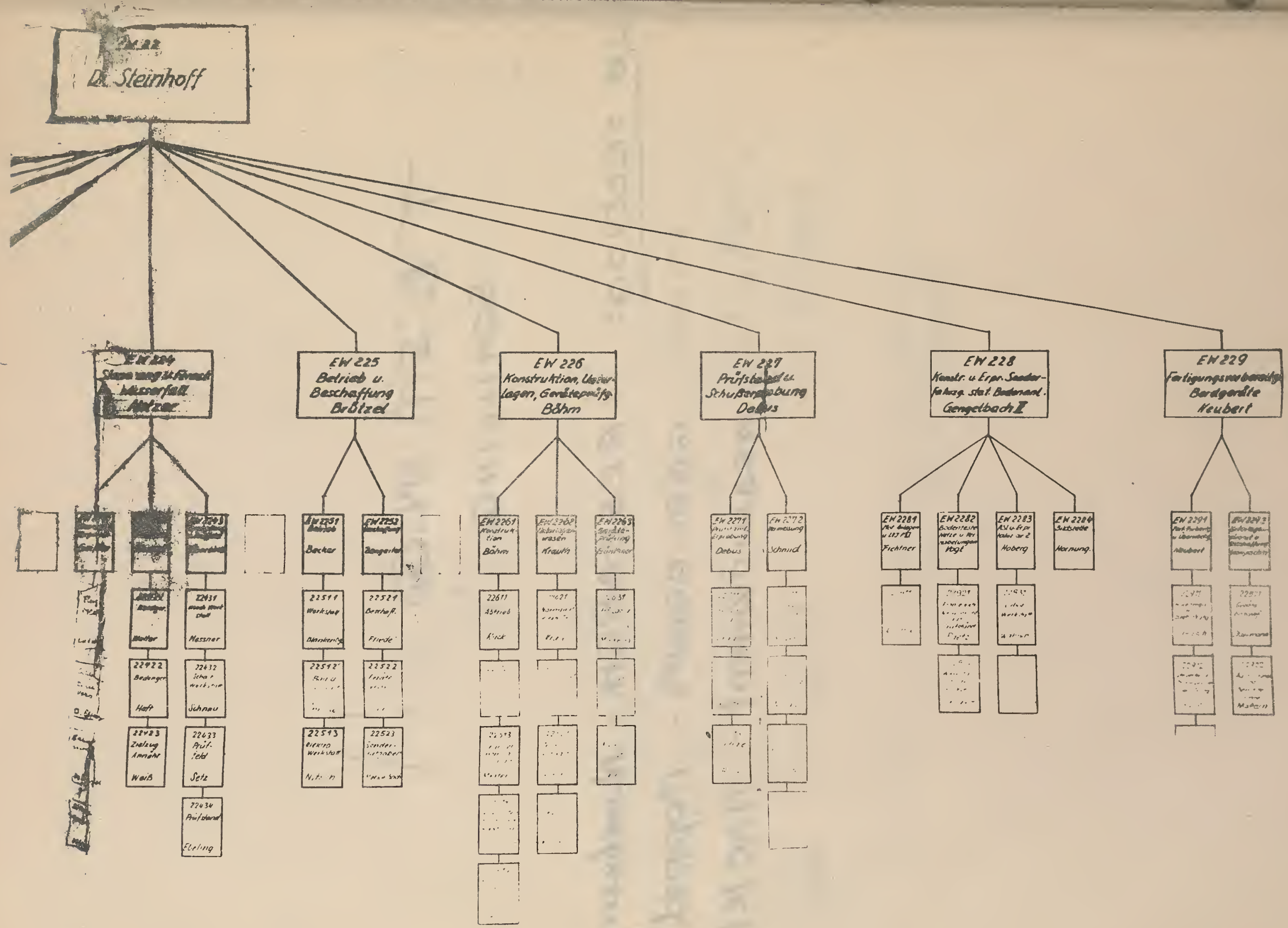
all at Blücherstr.
see Ord. Reports

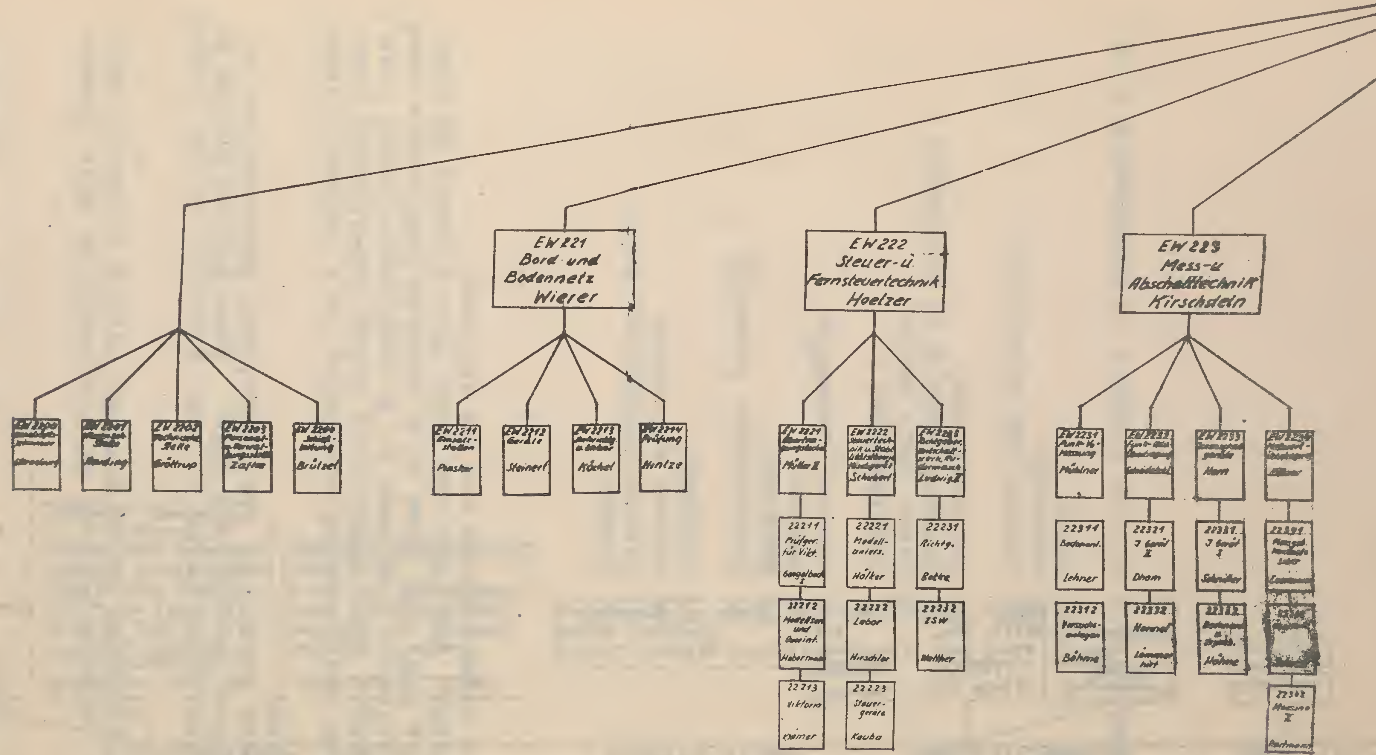
TESTING

SCHILLING.

sub sections

RESEARCH - Humburg
GRD: EQUIP: - Poppel
measurement - HACKh


Dr. Steinhoff
EW 225
Betrieb u. Beschaffung
Brötzel
EW 226
Konstruktion, Unterlagen, Geräteprüfg.
Böhm
EW 227
Debus
EW 228
Konstr. u. Erpr. Sonderfahrzg. stat. Bodenanl.
Gengelbach II
EW 229
Fertigungsvorbereitg. Bordgeräte
Neubert
EW 2251
Becker
EW 2252
Baugarten
EW 2261
Konstruktion
Böhm
EW 2262
Krauth
EW 2263
EW 2271
Debus
EW 2272
Vermessung
Schmid
EW 2281
Fichtner
EW 2282
Vogt
EW 2283
Hoberg
EW 2284
Hornung
EW 2291
Neubert
EW 2293
22431
Messner
22922
Haft
22432
Schnau
22923
Weiß
22433
Prüf-feld
Setz
22434
Prüfstand
Ebeling
22511
Werkstatt
22521
Beschaff.
Friede
22512
22522
22513
Elektro Werkstatt
22523
22611
Abtrieb
Kirck


EW 221
Bord und
Bodennetz
Wierer
EW 222
Steuer- u.
Fernsteuertechnik
Hoelzer
EW 223
Mess- u
Abschalttechnik
Kirschstein
EW 2203
Technische
Stelle
Gröttrup
Zafke
Brülzel
EW 2211
Pnaster
EW 2212
Geräte
Steinerl
EW 2213
Köchel
EW 2214
Prüfung
Hintze
EW 2221
Möller II
EW 2222
Schubert
EW 2223
Ludwig II
22211
Prüfger.
für Vikt.
Gangelbach
I
22212
Modellsim.
und
Bauint.
Habermann
22213
Viktoria
Kramer
22221
Modell-
unters.
Hölker
22222
Labor
Hirschler
22223
Steuer-
geräte
Kauba
22231
Richtg.
Bettke
22232
ZSW
Walther
EW 2231
Punk-Vz-
Messung
Mühlner
22311
Bodenanl.
Lehner
22312
Versuchs-
anlagen
Böhme
22321
J Gerät
II
Dhom
22322
Lämmerhirt
22331
J Gerät
I
Schnitter
22332
Höhne
Horn
22342
Messina
II
Hartmann

ORGANIZ TION CHART FOR ELECTROMECHANSCHE WERKE

Karlshagen Oct. 1944

GENERAL MANAGEMENT

GENERAL DORNBERGER AND STAFF

DEVELOPMENT (2) Prof v. Braun.

21

lanning (Danneburg)
- sign (Dannenberg)
- atic (Hellebrand)
- tabilits (Bronscheuer)
- Design (Schulz)
- erfall (Patt)
- m (Dannenberg)
- ittings (Mullinger)
- ts (Heller)
- at es (Steurer)
- ing (de Beck)

22

Electrical Apparatus (Steinhoff)
- Circiuts (Wierer)
- Control (Müller II)
- Operation (Brützel)
- Prelim Test (Böhn)
- Tests & Trials (Debus)
- Static Grd. Control (Frichtu)
- Assembly (Neubert)

23

Grnd. Equip. (Hüter)
- Building (Iührsen)
- Test Building (Tessman)
- Spec. Vehciles (Elmer)
- Transport (v Liebhaber)
- Spare Parts
- Construction (Weintraud)

PRODUCTION (3) Rees
- Control Planning (Kuers)
- Stores (Schäfer)
- Job Control (de Vries)

TESTING (4) Schilling

Research (Humburg)
- Wasserfall
- A-4
- Taifun

Grd. Equip. (Poppel)
- Test Equip
- Test Fields
- Test Bldgs.

Measurement (Hackh)
- Fuel
- Propulsion

ADMIN. (5)
- Lighting
- Transport
- Quarters

ACCOUNT (6
- Office

Organization of the Electromechanische Werke Peenemunde East.

Distributed to certain members of the staff of this Organization was an Organizations Plan, several copies of which came into out hands.

The framework described below is that detailed in the Organizations Plan dated the 1st. October 1944. Some 500 employees of the total of 4500 were housed in the Divisional Headquarters at Garmisch-Partenkirchen.

The Organization was arranged according to a decimal system in five main departments each department being sub-divided into sections and sub-sections. The head of a department would bear a single number such as EW2, the head of a section EW23 and a head of a sub-section EW235. The rank and file were denoted by four figure numbers. The organization was as follows;

1. Management.	
2. Development.	21 Design 22 Electro-technical work 23 Ground Apparatus 24 Progress
3. Works	31 Preparatory assembly 32 Erection 33 Stores 34 General Assembly
4. Test	41 Experimental 42 Power Unit tests 43 Controls and Test apparatus 44 Instrustional
5. Purchase	51 Orders and allocation 52 Accounts 53 Staff

The detailed organization of one section of Department 2 is shown on

Diagram number-----

The organization of the Elektro Mechansene Werke in effect at Karlshagen in October 1944 was as follows;

Supervision-General Dormberger and Staff.

The firm was devided under Prof. v. Braun into six departments.

(2) Development (3) Production (4) Testing (5) General Adm. (6) Accounts.

1. The Development Department (2) under Dornberger was further divided into 3 sections.

(21) Planning (Danneburg) (22) Electrical Apparatus (Steinhoff), 23 Gen. Equip. (Hüter). These three branches were broken down into smaller sections.

(21) Planning;- Design Gen. (Danneberg)
Static (Hellebrand)
Stabilitz Research (Bornscheuer)
A-4 Design (Schalza)
Wasserfall Design (Patt)
Taifun Design(Danneburg)
Fittings (Millinger)
Fuels (Heller)
Mat Research (Steurer)
Printing & Photo (de Beck)

(22) Electrical Appartus;
Circiuts (Wierer)
Control (Müller 11)
Measurements (Kirchstein)
Operations (Brützel)
Prelim Tests (Böhm)
Tests & Trials (Debus)
Static Grnd Outfits (Frichtu)
Assembly (Neubert)

(23) Ground Equipment;
Buildings (Lührsen)
Test Buildings (Tessman)
Spec Vehicles (Elmer)
Transport Service (v Liebhaber)
Spare Parts
Construction (Weintraud)

11. The production Dept. (3) was divided into four sectio[n]s
Admin (Reas)
Control Planning (Kuers)
Stores (Schäfer)
Job Control (de Vries)

111. The Testing Dept (4) was divided under the control of Schilling into three smaller departments;- Research (Humburg) Grd Equi[p] (Poppel) measurements (Hackh) as follows;

(a) Research Wasserfall
A-4
Taifun

(b) Grd Equip
Test Equip
Test Fields
Test Bldgs.

(c) Measurements;- Fuel & Propulsion

IV. The Genl. Admin. was divided into lighting quarters & Transport. The account Department was similar to any other business. See Chart

Person Interrogated	Subject	Interrogated By.
Axster, Dr.	Organisation of HAP Peenemunde and Electro mech Werkstatte	Miller and Stokes
Bachmann, Alfred Bergeler, Herbert Bippard, Ernst Buhl, Herman	Work	Zwicky
Barwald Rudolf	Motor Tanks	Liebhafsky, Iball Gollin
Bornscheuer, Fredrich	Life History	
Beek, Gerd De	" "	
Beier, Anton	Work	
Beier, Anton	Life History	
Braun, Prof. von Steinhof, Dr. Kirschtein, Dr. Mulhner, Dr.	Radio Aspects of A4 & Wasserfall, Homing systems and prox. fuzes	Block & Kraus
Braun, Von Dannenberg Klauss	Regulator Valve Design	Hull
Braun, Magnus Von	Spontaneous ignition time of mixed fuels	Zwicky
Braun, [illegible]	Long Distance Rocket A9 and A 10	Hull, Houss Porter
Braun, von	Further work on A4 & Taifun	Lieb & Gollin
Braun, Prof. Von	Discussion on Thrust Motors	Gollin & Stokes
Braun, Prof. von " Werner	Discussion on jet devices Wasserfall	Zwicky Hull
Braun, Magnus von	Life History	
Buchold, Prof. Theodor	Connection with Peenemunde Frequency regulating equipment Breenschluss & Compensation for errors.	
Billig	Work on Test Stand	I.L.G.

Bohm, Josef	Life History	
Bohm, Josef	Work on mounting of Control devices A4	Zwicky
Bringer	Work on Wasserfall	I.L & G.
Bauschinger	Life History	
Bergemann, Fritz	" "	
Broleman, Horst	" "	
Claus, Harpi	Work on Test Stand No. 11	L. & G.
Dannenberg	Work on Jet Motors in General	Zwicky
Dannenberg, Konrad	His work A-3, A-4, A-5	
" "	Life History	
David, Dr.	Career, Wasserfall	L & G.
Debus, Dr. Kurt	Life History	
Dahm, Werner	Taifun - Wasserfall	L. & G.
Dhom, Ing.	Work	
Dannenberg, Konrad Patt, Kurt Rosenthal, Goddfried Giese, Heinz Burhese	Details of Piping and Valving	
Dornberger	German Guided Missile Programme	(Krause & (Wilkinson
"	Taifun	Zwicky
"	Heavy Concrete Install. Calais	(Stokes & (Porter
Donaubauer, Mas.	Life History	
Dhon	" "	
Dhon, Friedrich	Work at Peenemunde	Sharpe-Kenney
Dornberger, Walter	Develop of Resonating duct motors - Drafting Room	
" "	Life History	
" "	Enzian	Block, Krause Lt. Fox.

Elfers	Projectile Stability & Design of the Einlenk Computer	Smith & Wilkinson
Elfers, Wilhelm	Stability of Control Equipment Wasserfall	Stokes
Eichler, Martin	Life History	
Eisele, Dr.	His Work	F/Lt Block
Friesé	Career	
Finzel	Work on A4, A5	
"	Life History	
Fichtner, Hans	Life History	
Fricke, Werner	Professional Career	F/L Block Iball
Fricke, Dr.	Rheintochter	Wilkinson & Iball
" "	Life History	
Friedrich, Dr. Hans	" "	
Georgii Walter J.O.	Interrogation	Smith & Wilkinson
Geissler - Klein	Wasserfall	Sharpe, Stokes
Geissler	Control - Wasserfall	Zwicky
Geissler, Ernst	Life History	
" "	Control of Wasserfall	Stokes & Porter
" "	Tie-in Hominghead of auto target seeking device	Smith & Wilkinson
Gengelbach, Hans	Life History	
Gitter, Helmuth	Work on Plotting & Trajectories of A4	S/L Sharpe, S/L Kenney
Gundel, Herbert	Life History	
Giese Heinz	Wasserfall	Zwicky
Haukohl, Joachim	Life History	
Hellebrand, Emil	" "	

Hellebrand, Emil	Work on Wasserfall	
Haberman, Helmut	Life History	
Hintze, Gunter	" "	
Hirschler, Otto	" "	
Georgii	Career	Porter & Stokes
Georgii	Aufbau der Deutschen Luftfahrt	" "
Hohne, Erie	Life History	
Holker, Rudolf	" "	
Hosenthein, Hans	" "	
Horn, Helmut	" "	
Horn	Work at Peenemunde	Stokes & Porter
Heller, Dr. Gerhard	Propellants	Zwicky
Heller	Life History	
Hirn	Work on Wasserfall	Liebhafsky & Gollin
Hoelzer, Helmut	Life History	
Hohne, Erich	Life History	
Horn, Helmuth	Work at Peenemunde	S/L Kenny, S/L Sharpe
Horn	" " "	Stokes & Porter
Huter, Hans	Life History	
Huzel, Dieter	" "	
Hubner	Work	
Heuer, Wilhelm	Work	
Hoffmann	Work	
Haft	Computing Elements for Wasserfall	Stokes & Porter
Hoyer, Ludwig	Work	

Kechel, Herbert	Life History	
Kaschig, Erich	" "	
Keifer, Karl	" "	
Kirschstein, Fredrich	" "	
" "	Work on A4	
Kirschstein Schuller Rosenthal	Measuring Apparatus Telemetering methods A4 & C2	
Kirschstein	Measurements A4	Sharpe, Kenny
Krauth, Walter	Professional Work	
Kreipe, Werner	Career	
Kuberg, Willi	Life History	
Kuchin, Hartmuit	" "	
Klein Johan	Servo Control Equip	Sharpe, Stokes & Porter
" "	Guiding Control, Wasserfall	Zwicky
" "	Life History	
Koster	Work at Peenemunde	
Lindenburg, Hans	Life History	
Lange, Dr.	V-2	
Lange, Oscar	Career	
Larssen, Nils	Developments of V-Weapons	
Larssen	Interrogation, General, other Personnel etc.	Norris
Larssen Kaust Nordt Ruppel Ditte	Meteor High Velocity Additional Interrogation	Haus & Hull
Muhlner	Life History	
Muhlner	Work	

Mickesheimer, Fritz	Career	
Manteuffel	C-02 Wagon	
Millinger	Life History	
Mrazek, Willi	" "	
Muhlner, Joachim	Work on Doffler	S/L Sharpe, S/L Kenny
Mettersheim, K. H.	Life History	
Metzer Theodor	Work on Wasserfall	Dr. Port & F/L Stokes
Mikutowski	Propellants V-2	Zwicky
Micklas	Work Servo Motors	Stokes, Porter
Netzer	Work on Wasserfall	Stokes, Sharpe
Netzer & Walter	Radio Control - Wasserfall	Sharpe, Stokes
Ottenthal	Steering Contro V-2	Sharpe
Patt, Kurt	Life History	
" "	Construction - Wasserfall	Zwicky
Pauls	Life History	
Palm & Mellar	Work - Wasserfall (Fuel	Zwicky
Pfaff, Helmut	Life History	
Puls, Wolfgang	" "	
Pflanze, Willi	" "	
Rosenthal	Infra Red Equip	Sharpe
Rosinski	Werner	
Reilman, Karl	Career	Gollin & Liebhafsky
" "	Life History	" "
Ricken, Wilhelm	" "	
Rosenthal	Career & Work	
Raithel, Wilhelm	Life History	
Reisig, Gerhard	" "	

Sandvoss, Walter	Life History	
Schilling, Martin	" "	
Scharnoski, Heinz	" "	
Schuran, Walter	" "	
Schwartz, Friedrich	" "	
Schmid, Helmut	Optical Surveys of the Orbits of the V-2	
Schmitt, Walter	Life History	
Schwidetski, Walter	" "	S/L Sharpe & S/L Kenny.
" "	Career	" "
Steinert Gerhard	Life History	
Stahl, Hans Joachim	Life History	
Steinhoff, Ernst	" "	
Schubert, Reinhard	" "	
Schubert, Reinhard	Work	Stokes & Porter
Strobel, Reinhold	Life History	
Schmuck, Hans	" "	
Schuller, Albert	Work, Thrust Measurement	Hal, GTG
" "	Life History	GI. BAS
SCHULTZ	" "	
Seifert	Taifun, Wasserfall	L & G.
Sahr		
Schweidetsky	Work at Peenemunde	Stokes, House
Strobel	Work - Peenemunde	Zwicky
Steinhoff, Ernst	V-2 Work	Zwicky
" "	Code Names, A-4 Radio	Sharpe
" "	Effect of Exhaust Gases on radio communication with rockets	Porter Sharpe Stokes

Steinhoff, Ernst	Radio Control	P.S.S.
" "	Sterring Equip. V-2	
Sanger	Propulsion nozzles for rockets	Morris, Hull
Sanger or Ing. Eugen	DFS Ainring	Milliken
"	Experiments for coal firing for athodyd	Block
Toennessen, Hans	Career	
Tutz	Career	L & G.
Temme, Heinrich	Life History	Porter & Stokes
Voegeli, Herbert	Life History	
Voigt, Alfred	" "	
Vowe, Theodor	" "	
Weirey Hans	Career	
" "	Life History	S/L Sharpe & Kenney
Temme	Auto stabilization Pilotless flying bombs	
Weirey Hans	Vehicles used for Electrical and radio gear at operational shoots of A4	
Weiss, Helmutt	Life History	
Weiss, Helmutt	Target seeking equip Ground to Plane	Smith & Wilkinson
" "	Homing systems	S.S.P.
" "	Homing Device, In fra Red	Zwicky
Zangl, Wolfgang	Life History	
Zoike, Helmut	" "	
" "	Operational Data of singly constructed parts of driving gear for the V-2	
" "	Interr. work on V-2	Zwicky
Zeiler, Albert	Life History	

Reports	By
Scheme of jet motors	
Contents of Rail Cars	
Documents removed from Railway cars at Peiting	
Letter to Commander of American Troops	Work of Leo Brandt & Kotowski
Rocket Development in Germany 1929 to 1945	C. Miller
Werner von Brauns Report - Development of Liquid Rockets in Germany.	
Rocket Motor Test Station.	
Natter interceptor project.	NAV TECH Mis.
Peenemunde windtunnel as an artillery aid.	Liebhafsky.

Rocket Development in Germany 1929 - 1945
Elecktro Mechanische Werke - Peenemünde

The use of the rocket as a means of travel thru space has been the subject of discussion among many men in the past and has proved to offer an outlet for the seemingly abstract views held by many German scientists. Similar to many other developments the first step in advance into space has been brought about as one of the necessities of war. A study of rocket development in Germany can best be illustrated as a study of the experiences and records of thousands of scientists, experts and workmen working under the direction of Major Gene Dornberger and Prof. Von Braun who were responsible for the management of the Elecktro Mechanische Werke - Peenemünde.

A number of inventors prior to 1929 had experimented individually in attempting to develope various types of liquid fire rockets, but in all cases their activities were curtailed due to the lack of financial assistance. After 1929, the foremost and most enterprising of these inventors, realizing the hopelessness of individual effort, dedided to form into groups and pool their resources in the hope that further developement may be resumed. One of these groups, the "Rocket Flying Field" at Berlin had a Werner Von Braun as a student among its members. This action of combining knowledge and money met with some success, and at first permitted of simple fundamental tests with rocket-combustion chambers, and later, small uncontrolled liquid rockets were actually fired. These rockets reached heights up to 1000 meters and were landed for further use by means of a parachute. Once again however the work of these groups was slowed down by the lack of cash.

In January 1930 a Walter Dornberger, an officer in the Reichswahr, and who had graduated as Dipl. Ing. from the Technisle Hochschule Berlin in 1929 was posted to the War Dept as a rocket expert. He was there given the assignment of developing rockets for war purposes by Major Gene D Becker who was then in charge of the Weapons Office of the War Ministry (See Org Chart R01). The only factory associated with rocket manufacture at this time was located at Wesermünde where black powder rockets for sea rescue work were produced. It can be readily understood then that Dornberger experienced considerable difficulty in obtaining a suitable building for development work and in placing orders with various firms for individual parts. A proving ground near Berlin was used for testing purposes.

After overcoming the initial difficulties the results were so favorable that the first large scale trial could be attempted in conjunction with troops in 1939. This trial was on a weapon of very light construction, of 10 cms diam, using a powder fuel, and having a range of 6 kms, The results of this trial proved that this weapon could be used to advantage in saturating a definite area with high explosive ammunition, and in this way part of the normal field artillery assignment could be carried out at less expense.

Further development was then undertaken on the transition to smokeless powder and temperative and sensitivity problems; then, after the construction of simple launching devices, the following weapons were developed in rapid succession:

(German Rocket Developement 1929 - 1945), continued

15 cm Nebdwerfer (Do werfer)
21 cm "
Heavy Wurfgerät
28 cm Heavy Werfer
32 cm Heavy Werfer
35 cm Heavy Werfer
Panzerwerfer
Panzerchreck

It must be borne in mind that the development of these weapons was always under the direction of Dr Dornberger, and, when he considered the propellants, construction and munitions etc satisfactory, further production was left to the industrial firms. A few of the firms producing fuels for powder burning rockets were WASAG DAG (formerly Alfred Nobel) and Wolfe and Son in the Walsrode.

During the period of developement on powder burning rockets Dr Dornberger having been assigned by the Weapons Office (see Org Chart No 1) to develope rockets for war purposes, had not lost sight of the significance of the liquid fuel burning rocket and considered it one of the revolutionary technical discoveries of the 20th Century. He had followed with intense interest the activities of the various groups of rocket enthusiasts, sympathising with their difficulties and anticipating their objectives. Realizing that without financial backing this phase of rocket developement was doomed to a serious setback or even failure, Dr Dornberger obtained the necessary approval to develope liquid fuel rockets for war purposes in 1932. In order to take advantage of the experience gained in the past by those working on liquid fuel rockets it was necessary to select men of outstanding ability from among the groups of inventors whose developements were most advanced. The first to be chosen and brought under control of the Weapons Office was Werner Von Braun who was considered to be more advanced than the remainder. This offered to Von Braun the opportunity to continue development on rockets, the future of which he was most enthusiastic and permitted him to continue study at the Technische Hochscule. Such men as Drs Riedel and Rodulf were quickly enlisted to aid Dr Dornberger and Von Braun(see Org Chart 1)

A small test field was set aside on the proving fround a t Kermmersdorf and the proof of the functioning of the liquid propelled rocket was established after tedious fundamental research in 1933. Often standing day and night at the construction bench, and in the workshops, these engineers calculated, drafted, and finally finished the first combustion chambers for the thrust of 300 kgs. The choice of fuel to be used was governed by performance data and of availability in Germany.

In the Summer of 1934 a trial was made on a small rocket A2 of 300 kg thrust and stabilized bz a rotating pay load and which reached a height of 2000 meters. In the interim, propulsion units with thrusts of 1000 and 1500 kg(exhaust velocities 2000-2100 m/sec and specific fuel comsumption of 4.59 per sec) had been developed at Kermmersdorf and tested on special test stands. It soon became evident however that Kermmersdorf was much too small for further development on larger rockets and more people would be required if a long range liquid fuel rocket was desired.

The Weapons Office attempted at this time to interest industry in the future developement of rockets but it was evident that past results were considered too questionable to justify the expense involved. Dr Dornberger
-ealized then that unless the Weapons Office continued with the work that rocket developement would remain at a standstill. He approched Generals Fritsch and Kesselring of the German High Command and explained existing conditions and future possibilities. His interviews were so convincing that his proposals were considered and then approved. Dr Dornberger then augmented his staff of liquid fuel experts by such additions from civil industry as he saw necessary (see Org Chart No 1)

In choosing a site for a rocket developement station several factors had to be considered and weighed such as (a) secluded position, far from large towns, (b) favorable weather conditions, (c) reasonably satisfactory communications, and Peenemünde on the Ost See was selected, here alone was it possible to have in Germany a range along the coast of 500 Kms with suitable observation posts. Construction of an experimental station was begun at this location in 1936.

It was already recognized at this time that the developement of rocke showed promise both in the field of aeronautics as well as in the army, therefore it was decided to build two separate establishments at Peenemünd one for the Air Force and one for the Army. At Peenemünde West an airfiel was built for testing rocket aircraft and pilotless rocket propelled aircraft as well as auxiliary devices for standard aircraft. At Peenemünde Ost comprehensive test beds and workshops were set up to test rocket drive and controls.

At a total cost of approximately 300 000 Gold Marks, a completely isolated but most modern and technically interesting station was constructe Notwithstanding certain difficulties encountered by this group of scientist in the skeptiaism shown by highly influential officials in the government including Hitler himself throughout the various stages of development during the war, this amount of money must impress people of all nations that Germany did consider the rocket as the future offensive weapon and would eventually replace the most effective bombing aircraft.

After the necessary developing facilities (high velocity wind tunnels, work shops, electrical facilities, teststands, ships planes and transport) had been installed at Peenemünde development of the A series made great strides. In 1938 the first trials were carried out with liquid fuel rocket of the A 3 and A 5 types which were fitted with an automatic control system and had rudders in the gas stream. These rockets reached a height of 12 Km when fired vertically and had a range of 18 Kms when fired at an angle. They could land in bad cases by means of a parachute and be used again. It was found however that such rapid progress could not continue without a corresponding proportion of set backs. Consequently, although an order, based on the trial performance of the A 5 had been given to produce a rocke A 4 having a range of 250 Km and a war head of 1000 Kgs, this could notbe continued with until further information was available and was therefore relegated to the background for the time being.

The development of this device necessitated the exploration of a difficult new technical field. To further aggravate conditions the program was reduced in priority in 1939 and part of the civil employees withdrawn. Progress could only be made then with the help of Field Marshal Brauchilesh
who placed soldiers from the front at the disposal of Dr Dornberger as engineers and workers, and with the help of General Skeir who carried out construction. Dr Dornberger himself was then made responsible for the

training of soldiers both for the purposes of helping the engineers and for the purpose of training in launching (see Org Chart No 2). From this time onwards the brunt of further development was left to Dr Braun.

In an attempt to obtain further data on control, aerodynamics and stabalization, hundreds of A 5 were fired in trials between 1936 and 1942. Only from the experience gained from these tests and the results obtained from wind tunnel investigations was it possible to proceed with the construction of the A 6. A few of the investigations are as follows:

(a) Wind Tunnel Tests at all ranges of air speed between 0 & 1500 meters.
(b) Stability of the rocket.
(c) Development of the supersonic wind tunnel and measuring methods.
(d) Test bed investigations on the combustion chambers and the complete propulsion unit.
(e) Investigations connected with the steering at all ranges of airspeeds covered by the rocket.
(f) Development of measuring methods for plotting the complete flight path.

The requisites for success were through long and productive experiments on combustion, pump and valves, controls, and development tests on all parts by thousands of engineers, experts and workmen. All this labor was rewarded on 3 October 1942 when the first range trial of the A 4 succeeded with sufficient accuracy of 4x4.5 Km dispersion to justify an order of mass production. This accuracy of aim was not considered altogether satisfactory by the scientists however and combined with other modifications approx 65 000 alterations were required before the A 4 could in the middle of 1943 be considered a real mass production job. It was about this time, 1 June 1943, that Dornberger was promoted to Major Gen. Another point of interest is that according to Genl Dornberger, the air raid of 17 and 18 Oct 1943 did not seriously hinder the working of the experiments at Peenemünde, the settlement only being destroyed.

By this time the development at Peenemünde Ost had grown to such an extent that it was decided to form the civilian personnel therein into a company with the Reische as the shareholders, this company was named the Electro Mechanische Werke, under the management of Prof. Von Braun. The internal organization for the company is explained in appendix A and described in Appendix B.

Gen. Dornberger and his staff of scientists were still not satisfied with the accuracy of aim of the A 4 and radio beam devices were developed to improve the lateral direction control and improved propulsion cut-off devices were tested to reduce dispersion in range. These inprovements hovever were incorporated in a small scale only and were chiefly used in the attack on the harbor of Antwerp. Another objectionable point which required further investigation was the fact that there appeared to be a weakness in the A 4 which caused 40 - 50% of these weapons to disintegrate at heights between 3000 and 5000 meters before striking the earth. Experiments toeliminate the weakness took months but eventually some improvement was noted in the year of 1944. From these facts it will be understood why Gen Dornberger objected to the A 4 being put into operational use but after 20 July 1944, total responsibility and time of production was placed in the hands of the SS. Gen Dornberger was left in the position of Technical Adviser and in charge of home organization only (see chart No 2)

Under this new organization Gen Dornberger with Prof Von Braun as h ead of the planning and design, attention to increase the range of the A and while never put into operational use range at up to 480 Km were sheived. This program had of necessity to be carried out on a reduced rate as in consequence at the increasingly air superiority of the allies. The development of AA rockets was given first priority and absorbed most of the personnel. A certain amount of work was however done on the A 9 which was a further development of the A 4. The A 9 had wings which enabled it to glide through the stratasphere. The flight path was thus increased to such an extent that the range of the A 9 was nearly double that of the A 4 or approx 600 Km for the same fuel consumption. A plan to install special control devices on the A 9 which would have given it the same accuracy as the A 4 was considered and it was proposed that the weapon should go into a vertical dive at the end of the glide as did the M 1.

No further actual constructional development took place on the A 9 due to the urgency of producing a defensive weapon rather than offensive. In this connection conditions had become so acute in Germany that in Dec 1944 Gen Dornberger was placed in charge of all rocket develppment and V weapons especially anti aircraft types in the hope that his experience may tend to ease the situation. In his attempts to produce a satisfactory AA weapon, plans were laid at Peenemünde to develope a guided anti aircraft rocket the "Taifun". The Wasserfall was smaller than the A 4, propelled by liquid fuel and guided by radio from the ground onto the flying targets. Successful tests on this weapon were carried out but series production was not achieved. The Taifun is a small ground to air liquid fuel propelled rocket launched from rails having a range of 12 kils and a war head of .00 gms. This weapon having a diam of 10 cms and length 220 cms may be fired from its projectors at the rate of 65 simultaneously or 65 spaced at 1 1/2 seconds intervals.

Meanwhile Prof Von Braun and his staff had been continuing with plans for future projects and had intended to design the V 9 winged rocket to carry a crew. For this purpose the rocket was to be equipped with a retracting undercarrigge, a pressurized cabin for the pilot, manuall y operated steering gear for use when landings and special aerodynamic aids to landing. The landing speed of the A 9 would XXXXXXXXXXXXXXXXXXXXXXXn XXXXX have been as low as 160 Km per hour. The piloted A 9 would cover a distance of 600 km in 17 minutes. In order to increase this range it was considered that a large rocket A 10 would be used for assisted takeoff upon which the A§9 would be mounted for the takeoff. By such a combination it was felt that the A 9 would have a range of 5000 Km both in the piloted and pilotless types. This combination A9/A10 would be launched vertically to obviate the necessity of erecting large ground launching devices.

However these plans were never carri further than test jobs of the A9 and drawings and calculation for the A10, as, due to the rapid change of the war fronts and the proximity of the Russians it was decided that Peenemünde must be evacuated. Gen Dornberger, in order to be in a better position to control the administration of AA rockets in a concentrated effort to oppose Allied aircraft moved to Bad Sachsa. He was very shortly followed by his staff in January 1944.

On March 31st the whole of the remaining personnel of the Electro Mechansche Werke and as much equipment as could be moved left Peenemünde and moved to the same district. It was found however that the food situation at that point was critical, all supplies having to be transported in and so all were dispersed in and around Blecherode where Prof Von Braun made his headquarters. An attempt was made to set up the lab equipment and continue work but once again the rapid advance of the Russian Armies caused them to hurriedly reload what equipment they could and to disperse it by freight cars and barges to various destinations. A portion of the staff and personnel left Blecherode but were overtaken a Garmische-Partin XXXX kirchen by the unconditional surrender of Germany.

In conclusion it is felt that the advance made in the development of liquid fuel rockets is remarkable when the difficulties encountered are considered. The scientists themselves are of the opinion that had they been permitted a free hand the A4 could have been put into operational use at least 1 1/2 - 2 years before it was. The success of this development may be attributed to the enthusiasm and energy displayed by Gen Dornberger and Prof Von Braun, the fanatical drive of the scientists and the devotion of the workers to the management of the Electro Mechansche Werke.

C. Miller.

Peenemunde prepares for War.

As mentioned elsewhere in this report rocket development was put on the "Secret" list in 1931 and all scientists allowed to handle these documents or continue their studies from that time were likewise sworn to secrecy. No meetings ever indicated any immediate war demand until just three months before England and the ~~United States~~ France declared war on Germany.

At that time the first call to Peenemunde was made and the following basic research scientists were also called:

- Dr. Buchhold
- Prof. Busch, Electro-technischne, Darmstadt
- Prof. Walther, Math., Darmstadt.
- Prof. Wagner, Phys. Chem. Darmstadt.
- Prof. Heuter, Electro-Tech. Darmstadt.
- Prof. Kless, Mech. Darmstadt.
- Prof. Thum, Machine Tools, Darmstadt.
- Prof. Wolmann, Schwachstrom Technik, Dresden
- Prof. Staeblein, " " Berlin (now deceased)
- Prof. Fassbender " " Berlin
- Prof. Heidebruch, Machinen Elemente, Dresden

(Wolmann, Staeblein, and Fassbender also are considered to be specialists in Fernmelde Technik)

The meeting to which the above people were called was known as "Der Tag der Weisheit". During the meeting these scientists were told about the large scale developments in rocket-propelled missiles and were given specific assignments. At that time, Dr. Steinhof was the individual at Peenemunde in charge of all of the electrical control and under him Dr. Friedrichs was in charge of development of the steering controls (but not of the Brennschluss control) Dr. Ing. Kirchstein was at that time working with Fassbender in Berlin, where he became associated with development of the W/T Brennschluss equipment. He later was called to Peenemunde and put in charge of all types of Brennschluss control. Mention also was made of Dir. Thiel, in charge of all chemical work at Peenemunde. He was killed in one of the early bombings.

The town of Darmstadt were most of the scientists made their headquarters fell into the hands of American troops on approximately the 6 April 1945 and the Combined Intelligence Objectives Sub-Committee team headed by Lt. Col. O'Mara immediately proceeded to see and interrogate Dr. Hans Busch in charge of the administration at the Darmstadt Technische Hochschule and then in rapid succession Professor Wagner on the physical chemistry on rocket fuels, Dr. A. Walther, mathematics research, Dr. H. Vieweg technical physics, Dr. Hans Rau, physicist, Dr. K. Kloppel on structures, Dr. Huter, specialist on electrical measuring devices and high tension currents, Dr. Theodore Buchhold, Dr. A. Thum on plastics. Dr. Ing Irebhebner, machine design, Dipl. Ing. Helmut Titschack on machine design, Dr. Rudolf Brill, Dr. Fassbender, Dr. Heymann, Dr. Fischer, Dr. Ing. Mohlner, Dr. Carl Heinz Sturm.

No documents of any importance were found at this target, the University being completely demolished with the exception of the Physical Chemical Building which had been badly looted leaving nothing of any value except personal correspondence with other scientists and of no technical important.

The following interrogations may shed some light on the above named scientists contribution to the Peenemunde activities:

MEMORANDUM: Interrogation of Professor Dr. Carl Wagner, Kitzingen, 28 April '45.

Professor Wagner was interrogated by F/Lt Stokes and Dr. R. W. Porter.

Professor Wagner was head of the Physical Chemical Section of the Technische Hochschule Darmstadt. He carried out research under the following given headings:

PEENEMUEDE

1. Thermo dynamic calculation of the maximum exit velocities and the maximum schub obtained from various fuels or fuel mixtures. This was in conjunction with Dr. Thiel.

2. Catalystic decomposition of hydro peroxide particularly at high concentrations between 80 and 90%.

3. Calculations on air velocity in wind tunnels and determination of limiting factors. This was for the aero dynamics Section at Peenemunde under Dr. Hermann.

4. Research on the prevention of corrosion on zinc surfaces either by using titanium oxide deposits or by the decontamination of brass. This work did not lead to any useful result and was carried out for Dr. Näder who was in charge of the Materialprüfungsabteilung at Peenemunde. Development of an electrolitic cell for use as a precision coulomb meter in conjunction with Professor Buchhold's integration accelerometer.

5. Research on conduction of electricity through liquids for the purpose of feeding electrical energy to gyros. Various type of solutions were examined, the last one which was considered satisfactory being a solution of calcium hydroxide in propyl alcohol and water. The principle problem was the avoidance of gas formation of the electros. The best results were obtained with silver electros.

R.L.M.

1. Determination of electron density in mixtures of oxide; for example, zinc oxide and gallium oxide. This was the basic result carried out with a view to examining the possibility of increasing electronic emmision from incandescent cathodes.

2. Determination of the phase diagram of the system potassium atimony telurium (this was carried out for possible application in photo cells).

3. Phase diagram of caesium and oxygen (application as above)

4. Determination of the conductivity of pyrities for possible use in short wave detection. This work was suggested by Dr. Welker of the Flugfunkforschungs Institute at Oberpfaffenhofen.

5. Determination of the conductivity of lead sulphide also for possible use in short wave detection. The conductivity was measured (a) with excess sulphur present (b) with a deficiency of sulphur and (c) with the addition of other sulphides such as bismuth sulphide and silver sulphide. This work was not completed.

Reichsamt für Wirtschaftsausbau, Berlin.

1. Research on the catalystic formation of ammonia and on the catalystic formation of sulphur trioxide. The only work carried out was in conjunction with sulphur trioxide using iron oxide catalysts the work having started about the Summer of 1944. This was basic research intended to examine the relationship between the output of SO_3 in relation to the changes taking place in the catalysts during the reaction. Work on the catalystic formation of ammonia had not yet started.

2. Research on the decomposition of nitrous oxide in contact with pure zinc oxide and mixture of zinc oxide gallium oxide.

Reichsforschungsrat, Berlin.

Theoretic diffusion occurring in multi-phase alloys, for alloys of iron and carbon or copper and silver. This work remained in the purely theoretical stage and no experiments had been carried out as yet.

D.V.L. Adlershof.

1. Research on the surface treatment of aluminium to increase electric conductivity between aluminium contacts. Professor Wagner's findings were published in an article in Luftfahrtforschung dated about the beginning of 1943. This work was done at the suggestion of Dr. Viehmann of the D.V.L.

Professor Wagner electrolitic cells were manufactured by the firm of Dr. Siebert and Köhn at Oberkaufungen, near Kassel, also by the firm of Klinger & Schmidt at Ilmenau (Thuring).

A SKETCH OF THE BASIC OVERALL PLAN WHICH WAS CONTROLLING THE SECRET RESEARCH OF THE PEENEMÜNDE SCIENTISTS AT TIME OF SURRENDER!

In the course of the designing and developing work concerning A 4 (V2) an aggregate was planed, and its design and pre-examination brought to a certain conclusion (A9).
This aggregate based on the idea to change the exclusively ballistic trajectory of the A 4 from the point of culmination into a gliding one by the help of additional wings.
The energy of the aggregate A4 stored up at the moment burning stopped would, in this case, not be used for the purpose of hitting the target with a high velocity, but would be consumed to a great extent during the gliding. This should yiedl a reduction of the velocity at the point of landing down to 200 m/sec.
By this the best possible range has been attained for an aggregate on the granted basis of fuel: alcohol and liquid oxygen. A further improvement is only possible by the application of a propulsion for marching at high altitude which compensates the little resistance there and changes the gliding into a horizontal flight. A more exact examination of this possibility proves that the technical expenditure exceeds the efficiency additionally gained, in case of using just the same principle of propulsion and the same fuels as in the main power plant but on a smaller acale.
But it is quite a different thing if a jet propulsion is used as a propulsion for marching, which does not necessitate a particular fuel as career of oxygen, but uses the surrounding air
There can be taken into consideration: a) V1 - power, b)Lorin-tube, c) high pressure tube.
a) the V1 - power plant yields a specific consumption of about o.9 g/kg.sec. It works intermitting, the air being soaked in automatically by the expelled gases. After the injection of the fuel and its explosion the escape of the firegases in the direction of flight is prevented by a Venetian blind. On account of its high consumption this power plant does not come into question for the purpose under consideration.

B7 Contrary tothe V 1 power plant which works under sound velocity the Lorrin tube is fit for super sound velocity. It works continuously. A pressure is produced in a reversed ventury by a-diabatic compression of the air flowing in. By injection of a fuel and its combustion the temperature is raised from about 300 to 500°K to about 2000°K. By the rise of temperature the velocity of the expelled gases is increased. The utilization of the rise of pressure by the combustion is not possible, as the entry of the tube system is kept open.

Thermodynamical Computation of a Lorrin Tube.

1) The specific consumption G/R of a thrust propulsion plant with air providing the oxygen is given by the formuler

$$\frac{G}{R} = \frac{1}{1+\mathcal{E}} \frac{g \cdot 10^3}{\left(X\sqrt{2g\frac{K}{K-1} \cdot R\sqrt{\frac{T_1}{N}\left[1-\left(\frac{pa}{p1}\right)^{\frac{K-1}{K}}\right]}} - \frac{\mathcal{E}}{1+E} \cdot W_{aggr}\right)}$$

There means G= consumption in kg/sec; $\mathcal{E}$ = ratio of weight of air and fuel; X = factor of velocity = ratio between the real velocity in the exit cross section and the theoretical velocity there; g=9.81 m/sec^2; k= adiabatic coefficient for air = 1.4, for fire gases = 1.2; R= general gas constant= 848 mkg/Mol; T_1= temperature in the combustion chamber in °K; M= average molecular weight; P_a/P_1= ratio of expansion; w_{aggr}= velocity of the aggregate.

How may be seen from the formula, the number $\mathcal{E}$ has the highest effect on the magnitude of G/R, as the other independent variables T_1, M, and $\left[1-\left(\frac{Pa}{Pe}\right)^{\frac{K-1}{K}}\right]$ are under the root. It can be shown besides that the change of   influences comparatively little those variables. It is, therefore, most important to get an $\mathcal{E}$ as large as possible. This problem depends exclusively upon the question of fuel. A fuel with a good property of ignition at a surplus of air and a high value of combustion is necessary. With normal gasoline $\mathcal{E}$ can be about 12, with pure ethane about 15. A remarkably better value of $\mathcal{E}$ can, however, be obtained by liquid acetylen, which can be stabilized by the addition of ethane or amoniac. It is possible to use this mixture under pressure without the danger of expplosions.

E is about 21 in this case, that means 40% more than with octane. The computation is, therefore, to be performed in the following with C_2H_2. The additional stuff is, for the present, neglected, as its amount has to be fixed by experiments. The equation for the combustion with a number of surplus of air λ = 1.6 (that means, there is used more than 60% of air necessary for a complete combustion on account of the stoecheometric equation:

$$C_2H_2 + 4O_2 + 15,04\ N_2 \rightarrow 2CO_2 + H_2O + 1,5O_2 + 15,04\ N_2$$

The temperature of the compressed air is: T_1=712°K; the temperature of combustion T_1=2160° K; the molecular weight M=29.4; the air fuel ratio E=21,1.

Applying a round value for k=1.2 and a ratio of expansion P_e/P_1=1:25, the specific consumption is: G/R=0.78 g/kg surplus of thrust sec. It is possible to improve this number yet by the application of a larger λ value, which increase E, too. However, the consumption shall be performed with this value for the present.

c) Figure 3 shows a tube, which works at a super sound velocity, but not contunuosly.

After the entrance of air, the fuel is injected, then a valve to the funnel, soaking in the air, is closed before the explosion happens and, therefore, an expelling in the direction of flight is prevented. This arrangement allows a utilization of the rise of pressure by combustion, and, therefore, a higher velocity in the exit cross section is obtained.

For a considerated propulsion only anarrangement comes into question according to b) or c). The Lorrin Tube (b) has the same ratio of pressure in the nozzles for compression and expansion. An augmentation of the velocity in the exit cross section is obtained only by the fact, that the temperature of the gases is raised by the combustion. This velocity raises, by the first approximation, proportional to the root of the ratio of temperatures.

At the arrangement (c) there is added the raise of pressure to this effect. How can be shown, the pressure is raised maximally to about five times. At maximum pressure the ratio of expansion is, therefore, 1:125; after the expulsion of 50% of the gases, this ratio is 1:62. It is, therefore, possible to reckon on an average ratio of expansion of 1:60. The ratio of velocities in the exit cross section then is for these two cases

$$\frac{W_2}{W_1} = \frac{\sqrt{1-\left(\frac{1}{60}\right)^{\frac{\kappa-1}{\kappa}}}}{\sqrt{1-\left(\frac{1}{25}\right)^{\frac{\kappa-1}{\kappa}}}}$$

wherein the adiabatic coefficient is about k=1.2. The said ratio is w_2/w_1= 1.09. An exact integration does not essentially change this value. By the compution, the possible gain by the arrangement (c) is obtained, but there is on the other side a considerable loss. Larger cross sections are necessary on account of the intermitting action. Supposed, the loading takes the same time as the expulsion of the pressure, the entry cross section will be doubled and, therefore, the resistance, too. It is clear, that, as the effective gain can only be due to the difference between the streaming velocities in the entry and exit cross section, there is no gain with the arrangement (c). The ratio of thrusts is 3:2 corresponding to the ratio of the velocities of expulsion of 1500/1000 as in arrangement (b), that means, if theaggregate is propelled by an effection thrust of 1 t, there act 2 t in the entry cross section whilst there are produced 3 t in the exit cross section. If the cross section of the air funnel is increased for 50% only, no gain of thrust will anymore be obtained. During the time the air valve is dosed, the force of reaction produced by the retardation of the air in the venturi, will not be exerted, but there can be shown, that the pressure of resistance is almost exactly the smae as for the stationary state.
For that reason the Lorrin tube only can be taken into consideration for the computation of the project.
On account of the said results we propose the following projects:
A) In order to get results as soon as possible, we propose to provide the aggregate A 9 (A 4 with wings) with an additional jet propulsion (Lorrin tube). The advantage would be that all the approved parts of the power plant can be used. The ascending trajectory similar to A 9 up to an altitude of 20 km with a velocity of 1000 m/sec in this altitude. The further trajectory: Horizontal flight with a constant velocity (1000 m/sec) propelled by the additional power plant, the thrust of which is equal to the air resistance (~1.2 t)..

The aggregate in manned, the pilot sits in a vacuumproof cabin. The landing is performed by means of the retractable under carriage and a headqhell. The wings have to be designed by the help of slots and landing flaps so that a londing velocity of 160 km/h cannot be surpassed and on the other side, the c_w -value during the ascending and horizontal and the c_a/c_w - value diring the horizontal trajectory becomes an optimum.

B) An essential increase of efficiency could be obtained by the choice of a new fuel [illegible] basis and the introduction of an approved design of the power plant. The advantages are obtained by:

a) increased mean density of the fuel.
b) simplified power plant
c) reduced net weight
d) increased volume of the tanks at equal size of the fuselage
e) increased safety.

<u>Results of the projects.</u>

Concerning A) <u>Assumptions for Computation:</u>

Fuels:liquid O_2, alcohol, and C_2H_2

net weight: 5 t

velocity in the exit cross section: 2030 m/sec

consumption: 145 kg/sec

entire volume of tanks: 10,5m^3

remaining rest of fuel: 300 kg

<u>Results</u> A computation of the trafectory yields, that, after an altitude of 20 km and a velocity of 1000 m/sec is obtained, an amount of fuel of 1600 kg still is to the disposal for the marching plant.

The consumption of the Lorrin tube for 1.2 surplus of thrust can be assumed to 0. 93 kg/ sec according to the given calculation of the Lorrin tube. Taking 1600 kg of fuel for granted the time of flight will be $\frac{1600}{0.93}$ = 1720 sec at a velocity of 1000 m/sec. The range will, therefore, be (Ascent, horizontal flight and gliding included):

1800 km

Concering B) <u>Assumptions for computation:</u>

Fuels: tetranitromethane, visol and C_2H_2

net weight: 4.7 t

consumption: 150 kg/sec

entire volume of tanks: 11.3 m^3
remaining rest of fuel: 200 kg
Results: An amount of fuel of 2850 kg remains to the disposal of the marching plant. That means a time of flight of $\frac{2800}{0.93}$ = 3000 sec. This corresponds to a range of 3100 km.

Shape of the Lorrin tube: The size of the entry cross section is obtained by the necessary weight of air G_L, the density of air , and a velocity of the aggregate W_{aggr} to:

$$f_1 = \frac{G_2}{1 \cdot W_{aggr.}} = \frac{19,65}{0,0165 \cdot 1000} = 0,319 \ m^2$$

The diameter is, therefore, 637 mm. The minimum cross section of the air funnel is obtained by:

where is V_2 = specific volume in the minimum cross section and w_2 = velocity of sound. That means

Analogous calculation yields for the venturi:
Minimum cross section f_m= 0,223 m^2 and 532 mm Ø ;
exit cross section f_a= 1.12 m^2 and 1200 mm Ø.
The shape is given in Fig.2, the angle of expansion being 25°.
Conclusion.
By the given first, rough considerations the range XØ of aggregates similar to A 9 with an additional marching plant is obtained

for case A) 1800 km
for case B) 3100 km

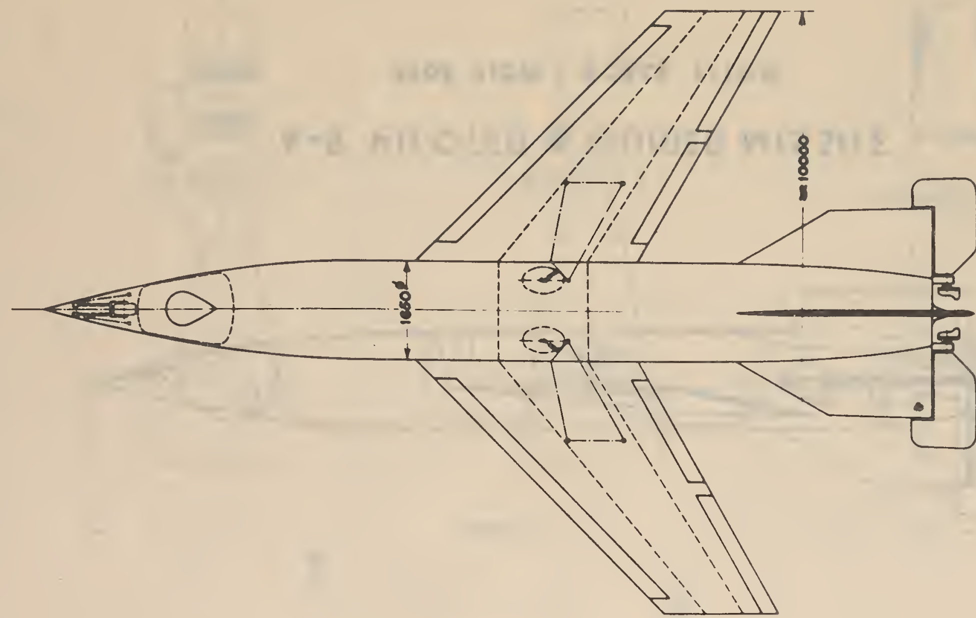
Since the calculation of the Lorrin tube follows purely theoretical lines and experimental results in this field are not yet known to us, the values given were to be able to be approved, yet. It is known, that power plants of this type were put into effect with a consumption of o.l g/kg.sec. Basing on this value, the given ranges could be increased on:

for case A) 13500 km
for case B) 23500 km.

The possible shape of performance of such an aggregate is given in Fig. 3.

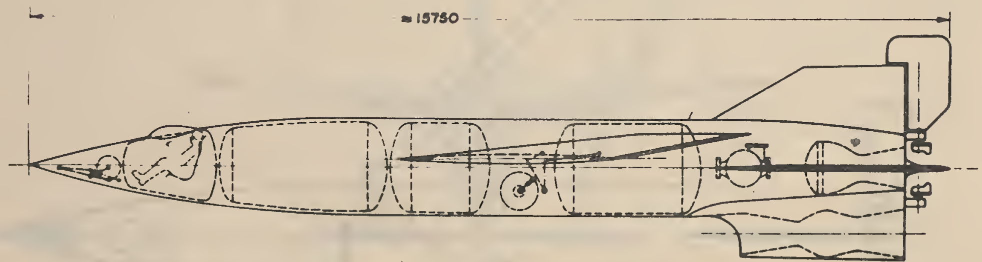
A-9 PILOTED & GUIDED MISSILE

REAR VIEW - SCALE 1 : 100



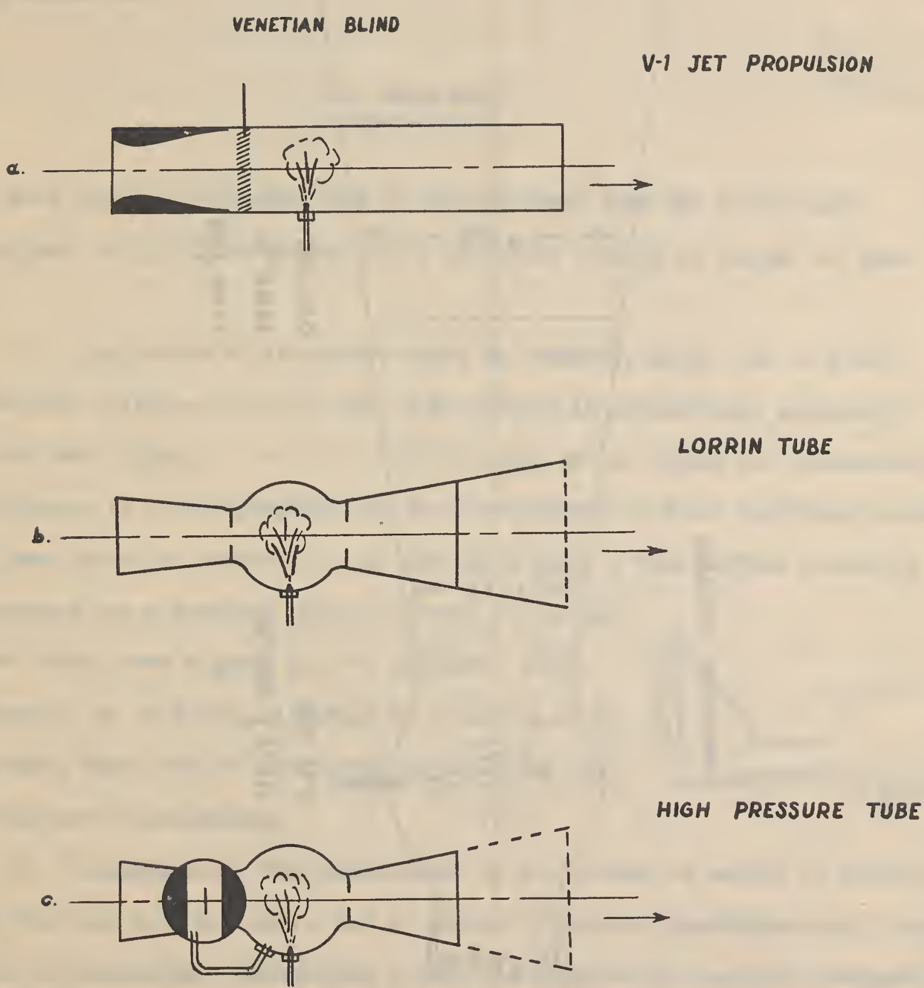
A-9 PILOTED & GUIDED MISSILE

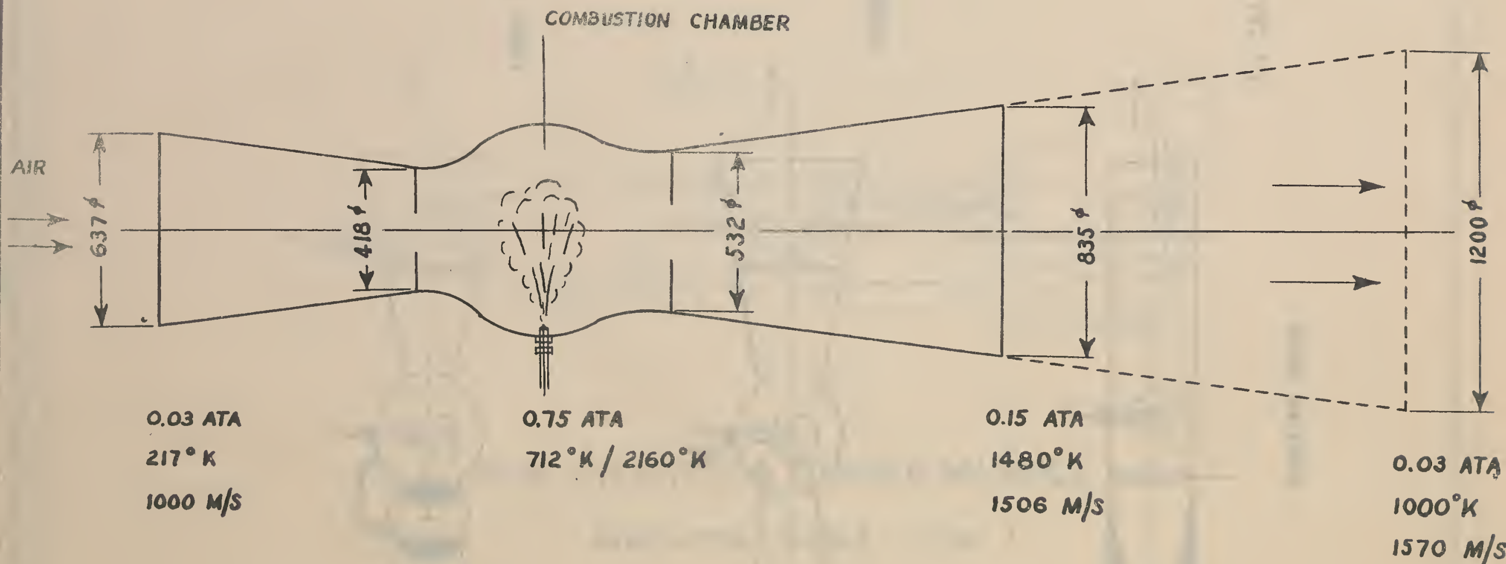
TOP VIEW - SCALE 1:100



A-9 PILOTED & GUIDED MISSILE

SIDE VIEW – SCALE 1:100


VENETIAN BLIND
V-1 JET PROPULSION
a.
LORRIN TUBE
b.
HIGH PRESSURE TUBE
c.


COMBUSTION CHAMBER
AIR
637 ϕ
418 ϕ
532 ϕ
835 ϕ
1200 ϕ
0.03 ATA
217° K
1000 M/S
0.75 ATA
712° K / 2160° K
0.15 ATA
1480° K
1506 M/S
0.03 ATA
1000° K
1570 M/S

T R A N S L A T I O N

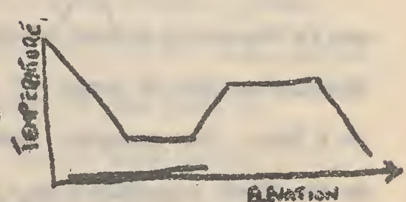
A. Walther, Darmstadt, 12 april 1945

32 Fichte St.

V-2 Ballistics

I have done the following work in this subject, only one of the many subjects of practical mathematics I have been working on during the war:

1) Application of literature about air density, wind, etc. at great heights. Discussions about this with experts in meteorology, especially with Prof. Wegener. Based on this figuring out of tables for temperature (Decrease in the troposphere, in the stratosphere at first remaining constant, then increase again because of the ozone zone, - then further remaining constant and a decrease again, as shown in sketch. The tables were figured out for pressure (air density) up to 100 km elevation in intervals of 100 meters, these tables then served as basis for all subsequent calculations.



2) Research about the oscillations of V-2 around its center of gravity in the wind tunnel. Linear law of damping (lineares Dämpfungsgesetz), cubic law of elasticity. Calculation of the oscillations by numerical integration of the differential equation with a factor (Koeffizienten) found experimentally. Then - the other way round - conclusions from the experiments in the wind tunnel on the factors (Koeffizienten) of said formulas, and working out of handy methods of exploitation for it.

3) Research about stability. A factor (Koeffizient) had been furnished by Peenemünde on the basis of experiments. With the help of this factor

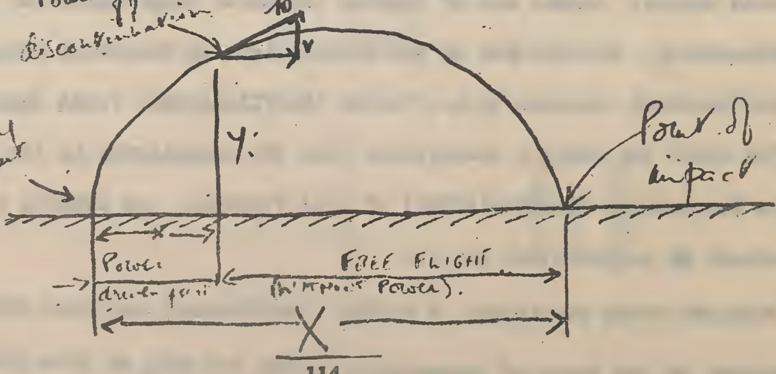
it was determined for numerous points of flight whether small oscillations will be damped (abklingen). In other words whether the flight of the V 2 is stable or not. For these calculations it was used: Criteria of determinants (Determinantenkriterion) by HURWITZ. Through variation of the factors (Koeffizienten), zones of stability were established. These zones were dependent on the factors. It became necessary to solve numerically equations of the eighth or tenth order — very difficult work — and this was done according to the method of the squared roots, using HORNER'S scheme in the complex (rational and imaginary values)

4) Calculation of the trajectory. The trajectory is subdivided into the power propelled part and the free flying part that follows. The beginning of the power propelled part is the starting point, the end is a point (x,y) where the power is discontinued. The total range of the V 2 is

$$X = x + f\,(y, v_x, v_y)$$

and is therewith mainly dependent from the height obtained at the time of the discontinuation of power "y" and the components (v_x, v_y) of the speed at THAT TIME. For example: consider the trajectory of free flight as a parabola in the first approximation — because the free flight takes places at great height in very thin air:

$$X = x + \frac{v_x v_y}{g}\left(1 + \sqrt{1 + \frac{2gy}{v_y^2}}\right)$$



In the power driven part of V-2's trajectory the projectile is being turned from the vertical position to the final starting angle by way of automatic control (Programmsteurung) in a predetermined way. With my collaborators I have calculated the shooting range for many cases, by way of numerical integration of the following five equations as far as the power driven part is concerned:

(1) Differential equation of the translation movement

(2) Differential equation of the axial movement

(3) Equation of the moments (Momentengleichung)

(4) Steering equation, that is to connect the trajectory angle,

(5) "Ruderwinkel" and Deflection angle (Anstellwinkel)

And by way of more simple differential equation for the free powerless flight. -- That way I gave complete information about the trajectory for the different given programs, heights and speeds at the time of the power discontinuation to form a basis for firing tables. The mostadvantageous form of the trajectory was made object of special research in order to obtain maximum range, furthermore the influence of wind - from the front, from behind and from the side, and of change of meteorological conditions, finally the influence of the earth's rotation, etc. The calculation of the trajectory was done by subdividing it into a medium course (Mittlerer Verlauf) and superimposed oscillations, after it had been proven by voluminous calculations that such a division is admissible. In order to simplify-further, the complicated function $f(y, v_x v_y)$ was linearised and tables were established of the applicable influencing lines values (Einflusszahlen). Of further importance was research regarding the degree of accuracy, how far X was influenced by variations of y, v_x, v_y and what was therefore required to keep these values in line.

For these trajectory calculations a staff of several scientists and about 30 female calculators with electric calculating machines was being employed. My calculating, the only one in Germany, consisted of about 90 people including shop and office personnel. Because of the fact that the work was very tedious and time consuming even with the best organization; I worked at the construction of a calculating machine for ifferential equations with the intention of using it also for many other purposes besides ballistics: establishing of tables for new functions and processing of differential equations in the field of natural sciences and engineering. About this I should make a separate report. Somewhat Vannevar Bush, the principle was the application of integration rolls (Integralenrolle) with photo-electric disk reading and follow-up (mit fotoelektrischer Kurvenabtasting und Nachführung) Experimental machines brought very good results. The construction of the complete machine has stopped to my regret - owing to war conditions. I hope to be able and wish urgently to bring this important development to a successful conclusion.

Furthermore I have worked on the mechanization fo calculations in order to facilitate and hasten this development by means of combining calculating machines and using punch hole system machines (Hollerith Lochkartenmaschinen). A similar system seems to have been achieved by the American calculating automat produced by AIKEN.

MEMORANDUM   Interrogation of A. WALTHER, TECHNISCHE HOCHSCHULE, DARMSTADT.
21 April 1945

PREVIOUS INTERROGATION

Subject had previously, under dateline of 12 April 1945 indicated his fields of work in connection with the calculation of trajectories for Peenemunde. His text (6 pages) and English translation of it (3 pages) are attached.

HISTORY OF PEENEMUNDE.

Subject gave summary of German rocket research from hearsay and experience. In 1931-2 all rocket research was put on the Geheim (Secret) list by General Dr. Becker, former chief of the Heereswaffenamt. All rocket researchers were given three alternatives:

1. Turn over patents and cease work
2. Be put in jail
3. If they were good enough they worked on government rocket program (at Kummersdorf)

Dr. Becker published a revised edition of Ballistics by Crans. The work at that time was on powder rockets. Principal collaborator of Dr. Becker was Capt. (now Maj. Gen. DORNBERGER. VON BRAUN came to Kummersdorf in 1932 right out of school. Dr. THIEL was already there having come to the attention of BECKER by a lecture he gave.

Subject believes that a beginning was made at Peenemunde - construction and layout - in 1936-7. The transfer of activity to Peenemunde from Kummersdorf occurred in 1938-9. Kummersdorf continued to work on powder rockets. Dr. THIEL was still at Kummersdorf in 1939. (THIEL was killed 18 August 1943 in raid on Peenemunde).

The Peenemunde program on liquid fuels was originally scheduled to be a long time project lasting about 8 years but the nazis insisted on results in two years. The pressure applied resulted in enlisting all possible aid from outside sources, particularly Darmstadt because several Peenemunde authorities had studied at the Technische Hochschule. Dr. STEINHOFF was formerly a student of Prof. Walther (the subject).

Darmstadt was so busy as a result that it could practically guarantee its people freedom from war service. The subject was drafted for one week before he was rescued.

The occasion of inviting in all this outside aid was the meeting at Peenemunde on Sept. 28 to 30 1939, list of attendants to which is included in the interrogation report on Dr. BUCHHOLD. This famous meeting as jocularly known among the professors as "Der Tag der Weisheit".

Additional persons present, not previously listed were:

PROF. SCHULER	Goettingen	gyro expert
PROF. BECK	Dresden U.	Motor transport expert
SCHILLER		
WEBER		
PROF. TOLLMIEN		

At the meeting Prof. VON BRAUN addressed them. He was the technical director of Peenemunde. There were lectures and discussions for three days to decide who would tackle each aspect of the total problem. The subject was in this and subsequent meetings assigned the problems enumerated in the attached text, namely air-tables up to 100km, stability problems and trajectory problems or firing tables. At this first meeting the military atmosphere was completely lacking. The subject went to Peenemunde subsequently about twice yearly.

Subject reports that the first successful start with V-2 was 3 Oct. '42. Production moved away from Peenemunde early but the research stayed until the raid in 1943. Then much of the research scattered to various places on the isle of USEDOM. Dr. STEINHOFF was in BANSIN, USEDOM until at least early '45. He then moved to a place whose postal address was NORDHAUSEN. Much of Peenemunde was believed now evacuated to region of Harz mountains (underground places in central Germany). Some portions went there as early as '42. The later movement from Peenemunde was done in a big hurry so subject cannot see how they could have taken all instruments etc. with them.

The Peenemunde wind tunnel reported to be good up to Mach number of 3 was moved. Subject believed it went to Bavaria because the trucks which carried it off had come from Bavaria.

PEENEMUNDE WIND TUNNEL

Subject did not profess to be expert on wind tunnels but gave the following remembered figures. The Peenemunde wind tunnel used a large evacuated sphere. Air rushing in was dried by special silica gel. No heating of the air was done. The measuring space had a square cross section of one to two square meters. Models were about 50 cm. diam. All sorts of super-sonic problems were handled - rockets, artillery etc. The Army had priority on the Peenemunde tunnel and the Luftwaffe had priority on a tunnel at Brunswick. The men in charge of the wind tunnel work at Peenemunde were DR. HERMANN and DR. KURZWEG. The Goettingen wind tunnel of Prandtl's did little work for Peenemunde because the Peenemunde men concerned had not studied there. They had studied under Prof. Schiller and Prof. Weber. Prof. Rau of Darmstadt would know more about the wind tunnel.

Another wind tunnel at Friedrichshafen is only good for Mach numbers under one.

SUBJECT'S CALCULATIONS

On air temperatures at high altitudes, subject worked with Dr. REGENER of Friedrichshafen. The latter had been removed from his post in Friedrichshafen by the Nazis and installed in the Forschungstelle für Physik der Stratosphere (Kaiser Wilhelm Inst.) He had investigated the stratosphere up to 28 km. with balloons. Both Regener and the subject were interested in meteorological rockets but did not use them. The particular investigation here used data available both in Germany and in America to calculate the temperatures in the ozone layer due to solar absorbtion. Thing work as producted so their calculations were believed to be accurate.

The subject, as a pure scientist, was convinced that the V-2 must be very accurate or there was no point to it. His firing tables were calculated down to meters. He thought in terms of accuracies of one part in ten thou. He was horrified to find that the gyroscopic integrating accelerometer was to give accuracies of only one in a thousand and even more so to find that in practice only 30 to 40 per thou. was the accuracy achieved. There was constant arguments between Peenemunde who wanted immediate results and the subject who wanted more accuracy.

Subject worked out the firing tables right down to numerical results. Prof. TOLLMIEN was assigned the same problems of stability and firing tables but worked them out with elliptic functions which were useless for field use. Subject's methods were numerical integrations. In the stability problem the differential equation to be solved was

$$m\ddot{y} + K_d\dot{y} + ay^3 + by^2 + cy = F(t)$$

normally the elastic force is considered to be linear which make a and b both zero but the subject retained these terms and solved numerically. This cubic elasticity law equation is useful also in vibration problems involving rubber.

The subject was very active on these V-2 problems in 1941 and 1942. After that the problems that Peenemunde furnished him were largely repetitions with different values of constants, and could be handled mostly by the subject's staff of calculators. Further, the mathematics staff of Peenemunde was able to handle most of what was required. Dr. Schroeder headed the Peenemunde math. staff. He was considered too abstract and one sided and was not liked. He was succeeded by DR. STEUDING. Other mathematicians on the staff were DR. STROBEL, DR. GEISSLER, DR. LUDWIG. The subject was the only mathematician outside Peenemunde who worked on these jobs.

MISCELLANEOUS

The subject was asked to prepare an outline of what problems he worked on after 1942 when he finished the V-2 work allegedly.

The professors of the Darmstadt region belonged to what was called a Vorhaben, Peenemunde (abbreviated VP) or Arbeitsgemeinschaft VP. There was another one in Dresden. Prof. BUSCH was the Vorstand of the Darmstadt one but his chief task was not the distribution of scientific tasks but negotiations with the Ruestungkommando to keep the organization together and maintain unity. BUSCH also worked on receivers for telemetering of information from missle to ground. FIRMA DR. HELL of Berlin also worked on this and on electron optic.

Subject worked on trajectories for three missiles called the K3, K5 and K12. These were designed to have ranges of 30, 50 and 120 km. respectively. They were of the type that is first shot from a gun and then receives rocket boost in flight. The assigned problem was to find if the optimum procedure is to burn the rocket in the beginning, middle or end of the trajectory, and with slow or rapid burning. Oberst GEIST suggested this problem.

MEMORANDUM: Interrogation of Professor Dr. Richard Wieweg, Kitzingen, 21 April '45.

Dr. Wieweg was interrogated by F/Lt Stokes and Dr. R. W. Porter.

In the following preliminary interrogation Professor Wieweg's principle work during the War was found to come under the following headings:

1. Basic research on general problems of friction and in particular friction in small bearings, instrument bearings etc. The aim was to find methods of reducing friction to a minimum. Possible applications of this work was the accuracy of fuses which depend on clockwork mechanism and similar devices in which the friction plays a role in the ultimate accuracy of the device. Another field covered the use of gyro and similar measuring instruments used in the A-4. Consideration was also given to the possible use of mass produced bearings as used by the Russians. This work was done by Professor Wieweg in conjunction with the department of Dr. Steinhoff.

2. Construction of flow meters in liquid oxygen and fuels as used in the A-4. These instruments were intended only for the test benches at Peenemunde and not for use in the missile itself. Professor Wieweg had no knowledge of the actual fuels which were used for testing as these were applied in numbered packages without any description. An accuracy of up to ½% was requested and the instruments were required to work up to 40 atmospheres. In conjunction with this work Professor Wieweg also examined a variety of artificial resins which were used in the construction of these instruments to prevent the chemical action of the liquid oxygen or the fuels. He found that the most resistant type of material was Thiokol plastic. This was in conjunction with Dr. Thiel and the instruments were built partly in Dr. Wieweg's laboratory and partly in Peenemunde.

3. Research was carried out at Peenemunde by Professor Wieweg on a degree of ionization in flames as produced by liquid and solid rocket fuels. In this case also the precise nature of the fuels was unknown but it was generally found that liquid fuels produced a uniform area of combustion whereas in the solid fuels considerable dust and fine particles resulted from the burning. A cylindrical condenser device was used in the actual measure. The purpose of the research was to determine whether the ionization trail from the A-4 would give rise to any difficulties in the remote control of the missile. These experiments were discontinued however as it was feared that any form of electrical remote control would have to be discarded as being vulnerable to jamming. The condenser device however was to be incorporated in some form of high range projectile for automatic measure of the degree of ionization at various levels up to 24 km. The limit of 1000 grammes was specified for the weight of the device but the final weight was 600 grammes. Professor Wieweg does not know if this was ever tried out at practice.

4. Construction of model testing devices and steering controls primarily for the A-4 and possible use in connection with torpedoes. This work was carried out primarily by Dr. Hämmerman and the device is said to be at Aschaffenburg.

Memorandum: Further Interrogation of Prof. Dr. WIEWEG, Kitzingen, 22 April, 1945

Subject was interrogated by R. W. Porter and F/Lt Stokes.

This interrogation was to obtain a clearer idea of the extent of the subject's work on the measurement of ionization in the flame (exhaust) of a rocket motor.

The first measurements were made at a considerable distance from the nozzle and were made around an arc of a circle in the horizontal plane and also some measurements in the vertical plane were made with the use of a long ladder truck obtained from the fire department. For these measurements an ionization chamber identical in design to those used in stratosphere research were employed. Before each test random ionization caused by cosmic rays etc were measured.

Later on tests were made closer and closer until tests were finally made in the luminious part of the flame. For this work a very simple arrangement of two insullated plates was used, measurement of ionization being made by taking values of voltage and current across and to the plates. Many experiments were made to find the best materials for the plates and the insulation. The final materials were a cheap grade of cast iron which had a hard glassy surface for the plates, and "bakelite" impregnated paper for the insulation. The device never was used for more than one test. A metal baffle was used to protect the insulation from the direct action of the flames. The longest test ever run was of the order of sixty seconds.

In the flame, maximum ion densities of about 10^6 ions per cc were measured.

This work was done at Peenemunde at a spot on the sea coast (about 100 meters from the water) toward the west end of the group of buildings. A special test cell was constructed. Many difficulties were encountered, since the whole test only ran for sixty seconds, and the first part was spoiled by large amounts of dust, and the last part by particles of the burner coming out. Both liquid and powder rockets were tested, the powder rockets giving considerably more ionization. The subject believes that incomplete combustion resulting in smoke particles tends to increase the ionization effect because the smoke particles act as a nucleus for the ions.

Frequently after a test it was necessary , according to the subject, to look around and see if all the test personnel were still alive.

R. W. PORTER.

MEMORANDUM: Interrogation of Dr. HANS RAU, Kitzingen, 21 April, 1945.

Prof. Dr. Rau was interrogated by F/Lt Stokes and Dr. R. W. Porter.

Dr. Rau was also one of the scientists who were called to Peenemunde for "Der Tag der Weisheit". His first instructions were to work out a method for determining the variation in density of the air in a wind tunnel near the model. This measurement was to be made with a high degree of precision if possible. The problem was actually given by Dr. Hermann, head of Abteilung A.A. However, Dipl. Ing. Rama and Dipl. Ing. Arnold were active in this work and Arnold in particular visited Darmstadt frequently.

His first solution was ready in the spring of 1941; all subsequent work consisted of improvements in accuracy or in technique. In his first instruments, for example, he used a "Zahlrohr" similar to the Geiger tube for measuring the ionization. Later he developed an ionization chamber of his own which was considered better for this purpose.

The system consisted of an X-Ray tube so arranged that a narrow beam of low energy (20 to 30 KV cobalt anode) X-radiation could be made to pass across the tunnel through small holes covered with plastic, and to emerge from the other side. A plurality of such pairs of holes was provided so that measurements could be made all around the model. Density was determined by measuring the absorption of radiation during the passage through the working section of the tunnel. Dr. Rau agrees that this method is not particularly accurate at best and like other methods can be used for qualitative results only, unless the flow is strictly two dimensional. He stated that the method was definitely not sufficiently sharp (not sufficiently good resolution, in other words) to be of much use in studying shock waves. However, nothing else was available at that time/

An order was given to Weiss, Vienna, for apparatus to measure density by an interferrance method. This was dropped however because some experiments made by Dr. Rau showed that the method could not work on account of the movement of the windows and walls of the wind tunnel under pressure.

The work shop at the T.H. Darmstadt received an order and drawings from Peenemunde to build a device to evaluate Schlieren photographs in such a way as to measure the density. This apparatuswas not quite finished when the bombing destroyed it (probably). Oberwerkmeister Max Hoffman was in charge of the work. Dr. Winkler of Peenemunde repeatedly visited Darmstadt in connection with this project. The drawings were not Geheim and might not have been destroyed.

Rau thought that the wind tunnel had been moved away from Peenemunde some time ago. The address he had most recently used was "Dr. Graf" Munich, Post Box --- (couldn't remember).

Other dispersal points of interest are:
(a) Hildburghausen, between Meinigen and Coburg (N-51) in the vicinity of the gas plant there were rooms which were at the disposal of the Physikalische Institute at Darmstadt T.H/ The rooms belonged to a Naval Research Institution known as F.E.P -3. The facilities were obtained for Darmstadt through Dr. Heinrich Fischer who was a former pupil of Rau's working on development of a Bildwandler for the Kriegsmarine. It is believed that at least a part of Rau's section planned to move there in case of trouble.
(b) Dr. Gebauer of Phys. Inst. received orders in connection with a short-wave generator called a Hall'sche Kammer from Nachrichten-Mittel Versuchs Kommando formerly of Kiel, lastly of Wolfenbuttel near Braunschweig.

(Other information obtained from one of Rau's assistants confirms the fact that Rudolph Gebauer was working on 12-20 on micro-wave work in the town of Constance on Bodensee.)

R. W. PORTER.

Memorandum.. Visit to Darmstadt on 25 April 45.

Places visited.. At the Technische Hochschule the high voltage laboratory of Prof. Hüter, and the laboratory of Prof. Busch were visited. Also the laboratory of Prof. Wagner was visited. The homes of Prof. Busch and Prof. Walther were visited.

High voltage laboratory.. Dr. Steul and Dr. Fischer showed us around the high voltage laboratory. Regular lecture and experimental apparatus for high voltage work constituted most of the equipment. High voltage transformers, sphere gaps for calibration, large cylindrical capacitors, strings of HV insulators, and a large impulse generator built by AEG were the principal items seen.

The Hüter pressure measuring devices were discussed with Steul and Fischer. A sketch was drawn, a copy of which is attached. These were ordered for the Peenemunde wind tunnel. The work was begun in 1940 and finished in 1942. The Xray system for density measurement was also reportedly sent to Peenemunde two years ago.

Busch's Laboratory.. In Busch's laboratory we found a room supposedly devoted to the testing of a telemetering transmitter called the Messina II. This work was done elsewhere, sent in for testing, and sent out. Samples of the transmitter, and measuring equipment such as a camera and oscilloscope setup, and other miscellaneous equipment were brought back. Allegedly, another party had brought Prof. Busch there two weeks before and had taken away all remaining papers of importance. Also allegedly, papers and equipment had been taken ~~with Dipl~~ by Dipl. Ing. Schnapper, Lutz and Hartmann, assistants who fled about three days before the American troops arrived.

Dr. Fischer... Dr Fischer volunteered the Information that he had done some research work on Infra-red detection devices some time ago for the Navy. He worked at Kiel, Berlin, and Gutteningen. He worked with Sparks of 1/2 microsecond duration and 10 watt seconds energy, from which all the visible light was filtered; lead sulfide cells were used asa detector, and range was measured. He was able to see ships at a distance of 6000 meters and probably could have increased range, but since the device could not see through fog the Navy lost all interest.

Prof. Busch's home.. Frau Busch was interrogated about her husband's work places but claimed to know very little. No trace was found from her or the people interrogated at his lab. of the so-called Busch's tower mentioned by Cmdr. Marchant's party.

Prof. Walther's home... This was visited, but we found that the other half of our party had preceded us there that same day, so no interrogation was performed.

Prof. Wagner's Laboratory... This is at the Tech. Hochschule. Large quantities of all kinds of chemical apparatus and chemicals were around. Some itmms were found and brought back which appear to be connested with the electrolytic cell Wagner designed for the Buchhold I-Gerät. This included some cells, unfilled, made of glass, with two M-shaped electrodes of silver wire sealed in at one end and with a sealing off tube at the other end. These were individually wrapped and of good uniformity indicating that they were probably of production manufacture. Some silver wire of the type used for electrodes was also brought back.

There were a number of small tubes of alloys such as $W Al_4$ and $U Al_4$ that were probably merely from doctorate theses investigations of phase diagrams but may indicate a special interest in uranium or alloys of this tyepe so were brought back.

Investigators... The investigators in this party were Dr. H.A.Liebhafsky, Capt. T. Drysdale, R.A.Soderman, and W. Hausz, all CIOS investigators.

W. Hausz. 27 April 45

TARGETS OF OPPORTUNITY CONNECTED WITH DARMSTADT TECHNISCHE HOCHSCHULE VORHABEN PEENEMUNDE

A. Dispersals of Professor Vieweg.

1. Bismark Tower, Nieder Ramstaedter Strasse, Darmstadt.

This location was visited by Colonel O'Mara, F/Lt. Stokes, and Dr. Porter. Dr. Phys. Theodor Gast and Dipl. Phys. (Fraulein) Alpers were found working there and were interviewed. The principal work of this Aussenstellen was the development of electrical equipment for measuring the properties of synthetic resins. The latest work along this line was an automatic bridge for measuring dielectric constant, power factor and the like. Incorporated in this bridge was a novel type of electrostatic voltmeter capable of very rapid response and at the same time high sensitivity. Dr. Gast claimed to have been visited by an intelligence team shortly after Darmstadt was occupied, to have gone to the AMG with the leader of this team, and to have obtained permission to continue his work, and that he had surrendered two copies (all he had) of a paper entitled "Ein Neues Statisches Voltmeter" describing his experiments. This paper was traced to the E.E.I.S. Seventh Army which was located at Darmstadt, where it was reported that both copies had been turned over to Com. Z. Paris and suggested that they could be traced through Captain Sam Lee at Sig. Sec. E.E.I.S. there. No further action has been taken along this line. The experimental apparatus at the Tower appeared to be nearly complete. In fact Dr. Gast said that he believed he would have it operating within a few weeks. Briefly the voltmeter consists of a thin sheet of foil suspended between two parallel plates in such a way that it is free to move toward either of the plates, being restrained only by a light spring action. The whole assembly is enclosed in a plastic box of unusual design. Movement of the foil is detected by an electrical measurement of capacity rather than by direct indication.

The only plastics actually made at the Tower were small amounts of polystyrol resins. Other resins were moulded or otherwise treated there, however, and for this purpose a reasonable amount of chemical and mechanical apparatus was provided. Dr. Gast was familiar with Professor Vieweg's work on flow and pressure meters for alcohol, namely Thiokol (Polyethylene tetra-sulphide) obtained from Thiokol Gesellschaft, and Vinidur (polyvinyl chloride) from I.G. Farben, Bitterfeld. For the liquid oxygen instruments, one can even use cotton or paper-base phenol-formaldehydes according to Dr. Gast, but Vinidur or Plexiglass is better. Oxygen tends to make all of the plastics brittle, but satisfactory operation for short periods of time is obtained.

Dr Gast was further interrogated at his home in Eberstadt, 164 Adolf Hitler Strasse. He said that Dr. Klingelhoeffer and Dr. Arnet had been working on the problem of electrical charged on the hull of the A4 Rocket and their possible effects on its operation. All of their papers and apparatus, he believed, had been removed to Kuenzelsau to the home or factory of Dr. Hausermann (see reference later). His understanding of the problem was that an electric charge could be built up during the flight of the rocket either by action of the jet, or by the friction of the air. This charge, if it should attain sufficient magnitude, could cause failure in the operation of the radio equipment because of interference from electrical discharge or corona. He said he thought some practical results had been achieved because he understood that radio control was being used on the A4 operationally.

Dr. Gast was asked about the testing apparatus designed by Dr. Vieweg for the Steuerung Gerate of the A4. His answer was that Dr. Haeusermann had done almost all of the work on that project at the dispersal in Jugenheim, but that he had been ordered to remove all of this work to his home in Kunzelsau before the occupation.

A copy of a thesis by Winifred Op elt entitled "Daempfung von Regelvorgaengen durch Verzeogerte Rueckfuehrung" which was done under the direction of Prof. Viweg was obtained from Dr. Gast.

2. Jugenheim, Alte Bergstr. 5 Workshop of Schwinn. This location was visited by Colonel O'Mara, F/Lt. Stokes, and Dr. Porter, accompanied by Dr. Koehler (German, see reference later). There was evidence which showed that electrical and mechanical developmental work had been carried on, but all material of interest had been removed. Dr. Haeusermann's name appeared on the door of one of the ... lockers. A large number of wooden boxes were piled in one corner of the shop, which were found to contain complete equipment for photostatic reproduction, and also some personal things belonging to Prof. Vieweg. A large lathe and a few other machine tools were still in the shop, and there was a small quantity of very soft aluminium rod in varying sizes.

3. Nieder Modau, Home and Laboratory of Dr. Hildebrand. The laboratory was formerly a Hitlerjungendheim, which was taken over by The Darmstadt, T. H. as a dispersal. Dr. Hildebrand was visited on two separate occasions, the first time by F/Lt. Emery and an interpreter, and the second time by F/Lt. Stokes and Dr. Porter. In the first interview he claimed to have been working on friction measurements on ball-bearing races until the end of 1942 and then on pressure measuring instruments until the bombing in September 1944. Since that time he had been trying to organise the Jugenheim dispersal and had done no development work, but hoped to work on tachometers. He claimed to know very little about Peenemunde.

since this story was contradicted by documents showing that he had been in Peenemunde a number of times, he was interviewed again and asked to explain in detail what he had been doing on each of these trips.

Prior to 1943 he apparently had been working on ball bearing problems as indicated in the first interivew. On 27 February, 1943, however, he was inducted into the army and went to an infantry training camp near Coblenz. After fourteen days he was sent to Versuchskommando Nord (which consisted of a group of mechanics and technicians) at Peenemunde. He appealed to a Dr. Schuler whom he knew and arranged to be sent back to Darmstadt in April 1943 to work on a Schaelterstands Messer (liquid level indicator). This was to be a device of the capacity type which would indicate accurately the level of liquid (such as rocket propellants) in a tank. He completed such an instrument and sent it to Peenemunde, but doesn't know whether or not it was ever used.

In addition to his development work he frequently acted as a courier, going to Siemens, Kuggel-Fischer, Kreisel Gerate, and other manufacturers to collect instruments and apparatus for the Hochschule.

During the summer of 1944 he went to I.G. Farben, Bitterfeld, to discuss the possibility of improved methods of manufacture for the carbon vanes for the A4 rocket. I.G. Farben had impregnated some samples of graphite with a synthetic resin and had sent some of them to Prof. Vieweg for tests of heat conductivity and resistance to high temperatures. Prof. Vieweg was interested in the combination of graphite with resin and sent Hildebrand to Bitterfeld to find out whether or not they knew about any materials which would stand the high temperatures required for the vanes of the A4. Also Dr. Vieweg had hoped that it might be possible to mould these vanes using a mixture of graphite and resin, because the method of manufacture from solid blocks of graphite was expensive and took a long time. I.G. Farben told Hildebrand that there was no material which would stand the required temperatures; however, he says that he later learned that Farben had a patent for treating graphite "electrodes" with phosphoric acid or phosphates, to prevent them from burning away, and understands that vanes treated in the way were supplied to Peenemunde. Tests on these vanes were reported to have been inconclusive. Dr. Hildebrand is reasonably certain that the vanes used in production are all made of untreated synthetic graphite.

In Oct ber 1944 Dr. Hildebrand took over the work which had been handled previously by Dr. Schneider another of Vieweg's assistants. (Dr. Schneider was killed during one of our raids late in September by a low-flying strafing aircraft.). This work had started with the application of resin impregnated paper to the construction of flares, originally made of aluminium. At the time he took over, Dr. Hildebrand says, the job consisted largely of experimenting with resins as bonding agents for the powder.

Ninety parts of the powder to ten parts of a solution of resin in benzol were used, the solution usually consisting of Trolitul (polystyrol), one part, benzol seven to ten parts. They also used a number of other materials including an acid-proof putty - trade name "Asplit" (phenol-basis) made by I.G. Farben, the exact composition of which was not known. A number of visits were made to a Dr. Kirschner, of Eisfeld, specialists in flares, at Silberhuette.

Dr. Hildebrand was asked particularly about solventless "varnishes" for the above applications and answered that there were some in existence and that they were tested, but he could not or would not give the name of any such material.

The last trip made by Dr. Hildebrand to Peenemunde was in February of 1943, when he went there to discuss the problem of speed indicators for the test benches. The device was known as a Drehzahl Messer and was wanted by Dipl. Ing. Schuler of H.A.P., Abteilung fuer Versuche, Group M.G. It was to be used with an automatic recording devise made by Hartmann and Braun, a sample of which Hildebrand intended to take back to Darmstadt; but at that time the recording devices had already been packed up for shipment away from Karlshagen. The frequency of the tach generator was to be 200 Hz., (12000 RPM) if directly connected, but it was intended that it would eventually be geared down four to one so that the frequency would be 50 Hz. The range was to be alternatively plus or minus one cycle per sec. or plus or minus five cycles per sec.

Dr. Hildebrand returned from this trip in early March and had been trying to prepare his laboratory at Nieder Modau since then.

At this laboratory we picked up a small sample of a synthetic rubber which was used in pressure and flow instruments. Dr. Hildebrand either could not or would not identify the material.

Also in Nieder Modau was a photographic reproduction establishment located at Peter Gemeinderstrasse. There was nothin of technical interest there. Apparently Prof. Vieweg's institute had planned to do photographic work for their public ations at this location.

4. <u>Kunzelsau</u>. Home and ironmonger shop of Dr. Phys. Hausaermann's family. F/Lt. Emery, Mr. Hauss, and NCO Grebstein, interpreter, visited this dispersal hoping to find Dr. Haussermann, Dr. Klingelhöffer, and Dipl. Ing. Arnet. No one was found but Dr. Häussermann. He stated that he had come by road with several others from Darmstadt, including Klingelhöffer, Arnet, and some soldier assistants of the former. Arnet started back to Darmstadt shortly before F/Lt. Emery arrived and was presumably somewhere on the way on foot. Klingelhöffer went on to Regensburg along with his assistants before the Allied occupation of Kunzelsau, while

Haussermann stayed on with his family. He insists that only one wagon load of the material and papers they took from Darmstadt reached Kunzelsau, the rest being destroyed on the way. This wagon is said to have contained only the lathe, grinder, and other miscellaneous tools seen by our investigators.

Dr. Haussermann worked at Peenemunde from December 1939 until May 1942 on stability calculations. The work was done under a Dr. Steuding who arrived at many of the same results as Prof. Walther, working independently. Several minor disputes arose between the two men over the question of which one had originated certain methods. In 1942 Haussermann came to Darmstadt where in addition to teaching duties he was assistant to Prof. Vieweg. His work for Vieweg consisted solely in working out a testing device for the rocket steering controls. There is one such device for the control of each axis, consisting of a pendulum, damping vane, and torque-motor capable of simulating the dynamics of the rocket itself. He was asked to prepare a paper on this device and on the test procedure used, including all necessary drawings and promised to have this paper finished by May 11. Col. Gifford, T-Force, Sixth Army has made arrangements to have Interpretor Grebstein collect the paper on that date and to forward it to CIOS Secretariat, London, attention Heath.

Dr. Klingelhoffer is alleged to have reported direct to Vieweg, and Haussermann insists he has no knowledge of this work.

5. <u>Darmstadt</u> Home of Prof. Vieweg. This house was inspected carefully by F/Lt. Emery who removed a number of documents relating to the administration of the Praktisches Physisches Institut of which Prof. Vieweg was the leader. Only one proved to be of interest, however, namely a file containing passes for the various assistants to go to Karlshagen, Berlin and other places. The other documents were returned.

B. <u>Dispersals of Prof. Walther.</u>

1. <u>Darmstadt</u> Home of Prof. Walther. Col. O'Mara, F/Lt. Stokes, and Dr. Porter visited this house because it had been listed in documents found in the Hochschule as the headquarters of the Praktische Mathematische Institut of Prof. Walther. Frau Walther was found there together with several young students who were still working at the calculation and tabulation of Bessels functions.

Frau Walther seemed unwilling to give any information until she knew exactly what Prof. Walther had said but after being convinced that he had been reasonably open she gave us a little information about the activities at the other dispersals and the people who had been working at them. A lot of documents were found of the usual administrational type, and several new compilations of Bessel's functions of various kinds. Nothing of a classified nature was to be found. All such papers had allegedly been burned or carried away to the dispersals.

Frau Walther, herself a Prof. Math., was asked why the various government organisations, such as RLM, and the like were interested in Bessel's functions. She continued to insist that it was all in the cause of "Science" and so on. She added however that the calculations covered integral orders to seven decimal places instead of five as in existing tables, and that some work was being done on tabulations of the one third order as complex numbers. The house was inspected as carefully as time and the conditions would permit, but there is a possibility that documents of interest might still be hidden in this location.

2. Arheilgen (near Darmstadt) Home workshop of Hündsdorf, one of Walther's technicians. Inspection of this location was made by Colonel O'Mara, F/Lt. Stokes and Dr. R. W. Porter. It was hoped that parts of Walther's computing machines might be found there, but the place turned out to be a very ordinary basement with a small work bench and a few hand tools. Spare parts were found for the standard makes of calculating machines and typewriters, but nothing of any technical interest. Hündsdorf was not there, but it seems obvious that the story told by his wife is true, namely that he makes his living repairing the calculating and typewriting machines used by the Hochschule, and in particular by Prof. Walther.

3. Niedernhausen Eleonorenschule. At this location Dipl. Ing. Thiel assisted by Dr. Ing Glaser and Dipl. Mat Sipf (Fraulein) worked with about fourteen girls on aerodynamic and stress calculations for Junkers, rocket trajectory calculations for H. A. P. and calculations of the characteristics of remotely-controlled bombs for D. F. S.

The school was visited by Colonel O'Mara, F/Lt. Stokes and R. W. Porter, and found to be closed and empty. The Burgomeister from whom the key was obtained said that Dr. Thiel had taken all of his papers away by courier several weeks before our troops came. His father-in-law was located and from him it was found that Thiel had gone to Constance. (Frau Walther told us that he came from Vienna and that he would probably go back there as soon as he could.). Fraulein Sipf probably went back to her home at 13 Weberstrasse in Frankfurt. A number of letters were found addressed to her from that location. Nothing is known about Dr. Glaser except that Frau Walther believes he came from Steiermark, Austria.

No classified papers remained in the school at the time of our investigation; however in spite of the fact that officers had been quartered there, a valuable library of recent mathematical and aerodynamic works was found and brought back to England. In addition a few papers and manuscripts by Thiel or Glaser were found which may be of some interest. Among other odds and ends was a tabulation of the metals used in aircraft construction and their designations.

4. Hohenstadt near Bad Wimpfen. Small School. This dispersal of Prof. Walther's was investigated by F/Lt. Emory, W. Hausz, and NCO Grebstein, interpreter. The group here consisted of Dr. Schöbe and Dr. Selow, ten girls and one student. The work done was said to be all of a purely mathematical nature, both of the leaders professing not to know what application, if any, was intended:

(a) A problem put by NVK was the calculation of Bessel's functions of integral orders, $J_n(x)$ where n = 1, 2, 3, etc. up to 35 and x varies from 0 to 65 in increments of 0.2. These were done to seven places.

(b) Selow had started, apparently as a Doctorate Project the calculation of Bessel's functions of the one-third order in the complex plane with the components worked out to five-place accuracy.

(c) Calculations were made for Telefunken of the propagation of electric fields over a curved earth. Wavelengths from 0.01 to 50 meters were considered, with the transmitter at 5, 20, 50, and 100 meters, and the received at 50 to 10000 meters height.

(d) Many small Gittersumen problems were assigned from time to time such as the evaluation of:

$$\sum_{n=-\infty}^{+\infty} \frac{\cos|na+b|}{|na+b|} \quad \text{where } \pi < a \leq 2\pi$$

and

$$\sum_{n=1}^{\infty} J(nd) \quad \text{where } d < 4\pi$$

(e) Several problems had been assigned connected with the calculation of the reflection coefficients of multilayer materials using different dielectric constants. In particular they had recently been asked to calculate the reflection from a three-layer material in which the dielectric constantin each layer varied linearly with depth. The slope of this linear variation was different in the three layers.

These mathematicians claimed to have no knowledge of any ballistic calculations or any knowledge of the application of their work. No classified documents were found although a thorough search of the premises was not possible because of limited time.

5. Hochst Probst printing works. Dr. Hoffenberth is supposed to have worked at this location with eight calculators and draftsmen on Mantienschen functions for the R. L. M., elevation angle tabulations for flak, and evaluation of wind-tunnel research. The printing works is on Adolf Hitler Strasse, and Dr. Hofferberth is supposed to live on Erbacherstrasse 56.

W/C Smelt who remained at Heidelberg will investigate this target.

7. Kempton Firma A. Ott and Firma Seltamann. Dr. I De Beauclair, and Dipl. Ing. Dryer, with five mechanics and one secretary were building a differential analyser and doing some preliminary work for a problem in Fourier synthesis of X-Ray structure investigations for the RLM. Ott was a maker of precision mathematical instruments such as planimeters etc. The project was to be moved to Seltamanns near there. Various parts are probably to be found at Ott, at Seltamanns and some in a cellar in Kempton which was used as a store room.

It was not possible to investigate this target from Heidelburg, but it was turned over to Colonel Gifford of T-force, Caft group 4, for assessment.

C. Laboratory of Prof. Busch. Prof. Dr. Busch's laboratory in the Hochschule was not dispersed as were many of the others because it remained in fairly good shape after the bombing of September 1944. This laboratory was investigated by Captain T. Drysdale, R.A. Soderman, Dr. H.A. Liebhafsky, and W. Hauss. One room was found which was supposedly devoted to the testing of a telemetering transmitter called the Messina II. The transmitter was constructed elsewhere, sent in for testing and then sent out. Samples of the transmitter, and measuring equipment such as a camera and oscilloscope setup and other miscellaneous equipment were brought back. Allegedly, another party had brought Prof. Busch there the week of 6 April and had taken away all remaining papers of importance. Also it was alleged by Dr. Steul and Dr. Fischer, who were found in the Hochschule, that papers and equipment had been taken by Dipl. Ing. Schnapper, Dipl. Ing. Lutz, and Dipl. Ing. Hartmann, assistants who fled about three days before the American troops arrived.

Frau Busch, who was interrogated at her home, claimed to know very little about her husband's work. No information could be obtained about the destination of the assistants, or about any other places where Prof. Busch's work might have been carried on. In particular, everyone seems to agree that there is no such place as "Busch's Tower" which was mentioned in a preliminary report by Com Marchant.

Dr. Fischer was asked about his work and stated that he had worked on Infra-red detection devices for the Navy, at Kiel, Berlin, and at Göttingen. Spark discharges of 1/2 microsecond duration and ten watt-seconds energy were used, which were filtered to remove all visible light. Lead sulphide detectors were used and conventional pulse gear employed to measure range. Ships were detected up to 6000 meters and the range might have been further increased, but since the system could not "see" through fog the Navy interest had been dropped.

Dr. Steul said that he was assistant to Dr. Rau and had been working on X-Ray pressure-density measurements and other problems.

D. High-Voltage Laboratory and Dispersal of Dr. Hiter.

1. Laboratory in Hochschule. Investigators Drysdale, Soderman,

Liebhafsky, and Hausz went through this laboratory with Dr. Steul and Dr. Fischer, mentioned in the preceding section.

Standard Lecture and experimental apparatus for high-voltage work constituted most of the equipment. High-voltage transformers, sphere gaps for calibration, large cylindrical capacitators, strings of HV insulators, and a large impulse generator built by A. E. G. were in evidence. There was nothing to indicate work of any unusual nature.

Prof. Hüter's small pressure guages were discussed with Drs. Steul and Fischer. A sketch was drawn, a copy of which is attached. These instruments were ordered for the Peenemunde wind tunnel in 1940 and the design was finished in 1942. It was also mentioned that the X-ray density measuring system had been sent to Peenemunde late in 1942 or early in 1943.

2. Steinbach bei Lohr am Main (not certain whether Steinbach is the name of a village or only the name of the man's house where the work is being done). Dipl. Ing. Steinbach and Dipl. Ing. Knödgen have been making samples of pressure measuring devices. This dispersal was not covered for lack of time, but might be investigated if a mopping up operation is desired.

E. Laboratory and Dispersals of Dr. Wagner.

1. Physical Chemistry Laboratory in Hochschule.

This laboratory was also visited by Captain Drysdale, Soderman, Liebhafsky, and Hausz. It contained large quantities of chemical and electrical apparatus of unusual design. Several electrolytic cells were found which probably are of the type which were designed for the Buchhold integrating accelerometer. There were a number of these, individually wrapped and of uniform construction, indicating that they had been produced in quantity. All the cells were unfilled and consisted of a glass tube somewhat less than one inch in diameter having two "M"-shaped electrodes of silver wire sealed into one end and an exhaust tube at the other. The whole cell when sealed and packaged would probably be four to six inches in length. Some silver wire, possibly of the type used for the electrodes was also taken from the laboratory.

A number of small tubes of alloys such as $W\ Al_4$ and $U\ Al_4$ were found. It is believed that these were intended for academic exercises but it is possible that these may indicate a special interest in uranium or in alloys of this sort. Samples were taken.

(No documents of any interest were found in any of the Hochschule Laboratories; they had been cleared, apparently, of such material).

2. Firma Klinger and Schmidt, Ilmenau, Thuringial.

This company which normally makes thermostats and similar devices has also been making Wagner's cells. It is believed that both this company and the one on the preceding paragraph made only the empty cell and that Wagner himself employed technicians to fill, seal and test the cells.

These two companies could not be investigated because they were not in the Sixth Army Group Area, but were turned over for investigation to the appropriate Caft organization by Colonel Gifford.

F. Laboratory and Store-room of Dr. Rau.

Dr. Steul, mentioned above, was interrogated at his family home in Heppenheim and offered to show us through a cellar in the Hochschule which had not as yet been investigated. F/Lt. Stokes and Dr. Porter went through this basement area carefully and talked further with Dr. Steul.

The laboratory contained high-voltage transformers and a special high-voltage generator and other apparatus normal to work on gaseous discharges and X-rays. In other rooms were found large quantities of lecture demonstration equipment and standard physics laboratory gear. One room however contained a large quantity of vacuum tubes and radio components, and several very high voltage rectifier tubes. This equipment, according to Steul, belonged to the Theoretisches Physisches Institut which was not actually a part of the Hochschule but used some of their facilities. This Institut was connected with the NVK (Nachrichtensmittel Versuchs Kommando), headquarters of which moved from Kiel to Berlin and finally in March to the Harz Mountain district. The branch at T.D.H. got most of their equipment away after the bombing, leaving only this one small room. Also in the basement in a different room, packed for shipping were some boxes of laboratory gear, including a Navy chassis which was said to be part of a radar set. AMG was notified of the existence of all of this equipment and will turn it over to the local Signal Corps SEIS.

Dr. Rau's papers were thoroughly searched and found to contain only two things of importance. First a thesis by Dr. Steul on the Stark effect in calcium radiation, and second a paper by Dr. Rudolf Gebauer on experimental investigations of the operation of a high frequency tube known as the Heil'sche Kammer. This latter gives sketches and performance curves showing better than 35% efficiency at 20 watts output on 18 cm wavelength. Magnetic fields are used to focus the electron stream and thereby improve the efficiency. Dr. Gebauer has gone to Constance with all his equipment and may have gone on to some other dispersal near there, the exact location of which is not known.

Steul states that his work was primarily a problem in physics, but that he had hoped it might have some application in astrophysics since calcium is so prominent in the composition of stars.

A sample which was constructed to test the cathode and anode of Gebauer's experimental tubes was found and taken away, but no specimens having a cavity could be located.

When interrogated about Dr. Rau's X-ray work for Peenemunde, Dr. Steul said that he (Steul) had helped with that work and had been to Peenemunde several times in that connection. His description of the apparatus checked with that given by Dr. Rau at Kitzingen. More important, however, was the fact that Dr. Steul had also been to the new location of the HAP wind tunnel, which he described as a small valley on the outskirts of a village named Kochel in the direction of Bad Tölz. This is on the eastern side of the Kochel See about 100 Km south of Munich. This information was given immediately to T-force and listed as a target to be guarded pending investigation. The tunnel was said to be still under the direction of Dr. Hermann.

Aerodynamische Institut Dispersal, Jugenheim.

At the residence-cafe of Herr Schramm, Felsbergstrasse 3, Colonel O'Mara, F/Lt. Stokes. and Dr. R.W. Porter found a rather expensive store of instruments and equipment belonging to the Darmstadt T.H. This equipment had been used by Dr. Scheubel, head of the Aerodynamisches Institut, at the Greisheim wind tunnel and laboratory. Dr. Koehler was found there preparing to remove some of the equipment to his home. This equipment was reported to the AMG and also as a stock of instruments found in Koehlers home in Seeheim.

Dr. Koehler accompanied our investigators to Griesheim where both the Darmstadt, T.H., tunnel and the D.F.L. tunnel were inspected. Asked about experiments on the effect of intense electrostatic fields on the flow of air around a foil, he replied that such experiments had been carried on in the DFL tunnel but that he knew nothing about the results. He added that Dr. Steinhof of Peenemunde had come to the DFL in connection with this work bringing assistants with him. Dr. Scheubel, he thought, would know what had been done.

It was later learned that a report on this work has been picked up by CAFT from a man by the name of Dr. Ruchti in Darmstadt. W/C Smelt expects to interview Ruchti about Steinhof's interest if time permits.

Dr. Koehler also accompanied the investigators to the home of Dr. Ing. Getto, Eberstadt, Elfengrund 26. Getto has done some work on the distortion of the tail surfaces of the DO217 at speeds up to 0.8 Mach, taking into account compressibility. A copy of the late edition of Prandtl's book belonging to the Technische Hochschule was removed from his library.

H. Stotz Apparatebau GMBH Eberbach Manufacturer for Dr. Buchhold.

This instrument factory was first visited by F/Lt. Stokes, Dr. Porter, and Mr. Hauss and then again visited by F/Lt. Emery, Dr. Liebhafsky and Mr. Hauss in order to pick up some parts promised at the time of the first visit and to investigate rumors of additional rocket work, said to have been going on in the basement.

Dr. Steul was also the source of a slightly different picture of Dr. Klingelhöffer's work. According to Steul, the "electrical length" of the rocket changes during the power flight because of the presence of a highly ionized gaseous "tail". Klingelhöffer was studying this effect and attempting to find an "equivalent" length for use in radio antenna calculations, and the like.

The plant is in excellent condition with large stocks of raw materials, partly finished parts, and completed parts. Items manufactured in quantity were small switches and circuit breakers for aircraft, aircraft generators, and parts for the A4 program. Among the latter were pressure measuring instruments designed by Prof. Hüter, the BMK (Buchhold Messkopf) which is part of Buchhold's new range control, servo-motor assemblies for a stabilized platform to have been used in a more accurate type of range control developed by Buchhold, and, at the Heidelberg plant, wiring harnesses for the A4 production. Tools and fixtures for Heidelberg were made at Eberbach, which until the middle of March employed about a thousand workers. Three quarters of these workers were women and ten percent foreigners.

Dr. Ing. J. Moeller, technical direct both at Eberbach and at Heidelberg, was interrogated in addition to Dipl. Ing. Carl-Heinz Stürm, development engineer and chief of the laboratory, Dipl. Ing. Schäfer, and Herren Käfer and Kuhnert.

It was alleged by all of the above that the government inspector, Herr Lauer, burned all old drawings and took away all of the current drawings and all parts and assemblies in any way connected with secret work, before occupation. The transportation used came from Stuttgart so it is assumed he took them there. The date when he completed the removal was March 29. Under pressure however, many "bits and pieces" were found in waste piles and drawers. Finally Dr. Moeller agreed to assemble a complete BMK out of these pieces, making such parts as were missing. This was picked up on the second visit and appears to be an excellent job. A number of additional parts were also taken, and a few parts drawings, an assembly of the development engineer, and testing instructions as well. Although Wagner's integrating cells were mounted on the assembly by Stotz, no sample could be found. The only part of this device which remained was the thermostat and part of the cardboard case.

A complete list of component parts of the BMK and the names and addresses of the suppliers were obtained from the engineers.

The man in charge of shipments said that the BMK units were shipped to the following destinations: Technische Hochschule, Darmstadt, Firma Albert Bussinius of Dresden, Siemens Halske in Vienna, and to Nordhausen. The records indicated that Stotz had made about 1000 BMK's altogether, 20 in May 1944, none in June, 70 in July, and then a rapid buildup to 200 per month which continued through February 1945. The method of part manufacture utilizing pressing, forming and punching operations indicates that large quantities were intended. Siemens of Vienna made about 300 altogether according to Moeller, but went out of production when Stotz reached the above rate.

The Hüter gauge consisted of a metal Bourdon tube with a magnetic armature and two coils arranged for telemetering. They were made in blocks of four on a single base. The original order was for 1000 units, but work was stopped about a year ago after only about seven hundred had been completed. They were believed to have been used in remote indicating pressure gauges for V-weapon tanks (probably VI). All of the Stotz engineers claimed to know nothing of the smaller gauges designed by Hüter for the Peenemunde wind tunnel, or of the tiny quartz Bourdon tube units used on some of the A4 rockets.

A large number of the servo-motor assemblies were found in the shipping room. Dr. Moeller said that at one time it had been intended to use two BMK's on each rocket and in that case these servo-motors would have been needed. The plan fell through, he said, and the servo motors were not used. (This story checks with Prof. Buchholds plan to use two accelerometers mounted on a stabilized platform.).

The laboratory at Eberbach is large and well equipped. A number of precision instruments, and components were observed in cabinets on the wall, and in addition there were a lot of boxes in the cellar which contained additional laboratory equipment. These were marked "Lab. 19". The work of their laboratory was said to have consisted only of testing the manufactured products and of the development of a hysteresis-type tachometer for aircraft engines. To have secured the equipment they had on hand, however, they must have had influential friends in high places or a high-prority project.

Ing. Stürm seemed to be very proud of the tachometer development. He claimed that it was extraordinarily accurate and was essentially independent of temperature. A sample of this instrument and a tach generator used for testing it was taken. Stotz would be ready, apparently, to go into production on this instrument if there were any customers. No model of this instrument with more than one pointer (for multi-engine planes) has been designed.

One other item which Stotz Eberbach has made in large quantities, and which may be for the basis of a peace-time business, is a cable connector of watertight design for use on airfields and for other temporary cable installations.

I. Stotz Apparatebau, Heidelberg, Manufacturing A4 Parts.

This plant was visited, at a later date, by Mr. Hausz, W/C Smelt, and F/Lt. Emery.

Dr. Moeller was found in Heidelberg at the time of this visit and upon further interrogation he finally admitted he knew more about the A4 program than he had told during previous interviews. He was directed to write the fullest possible account of everything he knew and to have it ready by May 7, 1945. Arrangements have been made to have this paper picked up by the Sixth Army and transmitted to London.

The Heidelberg factory produced nothing of particular interest since it was engaged only in large scale production of components and its laboratory did nothing but test these components.

Incidental information obtained from Moeller at this interrogation includes the following:

(a) Components for the A4 rocket were covered by the code KHE. For example, KHEf 20 155-01 was one of the the ground connection plugs.

(b) The following firms were engaged in production of A4 components:

Sieberg und Kühn at Ober Kauffingen bei Kassel (Large scale electrical parts).
Josef Mellert, Bretten, Baden
Firma Caressa, Bammenthal bei Heidelberg.
Firma Krone, Stadhagen bei Hanover.
Firma Widmann, Zullichau, East of Berlin.

(c) Firms producing the Electronic part of the Buchhold range control, known as the Netzteil are:

Siemens, Werdau im Sachsen.
Bussenius, Pulsnitz bei Dresden.

(d) Although the initial order for Buchholds Messkopf was 1000, placed between one and two years ago, an additional order for five thousand was placed through Siemens, and great pressure was applied to speed production in August, September and October, 1944. As a result, much of the work was sub-contracted. All sub-contract drawings can be identified by the code BMK. A complet list of the names and addresses of the sub-contractors was obtained and is included with the other lists taken from Eberbach.

J. R, Jung Fabrik, Heidelberg. Heppelstrasse 46.

This small plant was investigated by W/C Smelt, F/Lt.Emery, and Mr. Hausz. It is a precision scientific instrument factory, undamaged, and in working condition. Normally employs 120 workers. A few of the parts for the BMK were made; otherwise they had been making microtomes, viscometers and other purely scientific instruments.

K. <u>Hilderghausen, FEP3 Dispersal, also connected with Darmstadt, T.H. Dr. Fischer.</u>

FEP stands for Forschung, Entwicklung, und Patentwesen, an organisation controlled primarily for the Navy. This organization originally intended to establish a laboratory in the T.H. at Darmstadt, but after the bombing decided to go instead to Hildberghausen. Before the move was complete, however, the organization, or at least the particular branch concerned, was dissolved, and Technische Hochschule took over the space in Hildberghausen. Dr. Fischer who had worked with FEB3 in Berlin was to be in charge.

Fischer was interviewed at his home in Darmstadt by F/Lt. Stokes and Dr. Porter. He claimed to be an expert on gaseous discharge and infra-red technik. He worked originally with Dr. Rau on the X-ray density measurements, then went to Berlin where he worked for OKM, a Naval establishment, until Autumn, 1944. The work in Berlin consisted primarily of anti-infra-red equipment for submarines (detection of our infra red equipment) but he also worked on a pulsed system of ranging using a 60 cm searchlight with a spark discharge. This system was successful in detecting ships up to ranges of 6000 meters under favorable conditions, but was unsatisfactory in bad weather. At the same time a lot of work was done on infra red cells generally, at Hildberghausen as well as at Berlin. Lead Sulphide cells were the basis of this research, but the addition of other materials and improved techniques of construction gave considerably improved performance. Operation in the region of 3.5 mμ was considered satisfactory.

Dr. Fischer stated that all his apparatus and papers were at Hildberghausen and that a freight carload of instruments from Berlin had been on its way shortly before occupation. Also he believed that Professor K.W. Wagner, head of FEP3, former President of Reichsforschungs Institut, and Professor Walter Weizel of Bonn University had taken refuge there. He asked that if possible he be taken to Hildberghausen so that he could properly identify the apparatus there and keep it from being "unnecessarily destroyed."

This information was turned over to Dr. Brode of Nav. Tech. Miss. Eu. and Lt. Mays, who agreed to talk with Dr. Fischer and possibly to take him to Hildberghausen if they thought his work of sufficient interest.

L. Dr. Ing. Hans Hyman, Forschungs und Prod. Messtechnik Auerbach, near Bensheim.

Com. McAuley and F/Lt. Emery investigated this underground plant and found a complete shop for making and testing aircraft instrument gyroscopes. As indicated in the initial report by the CAFT assessors the machinery was found to be rusting because of lack of protective coatings, and in addition it was found that most of the instruments, cathode-ray oscilloscopes, and other measuring equipment had been removed from the test benches. On the other hand the plant seemed to be in no danger from flooding, as was suggested in the initial report, since it was so arranged in the side of a hill that natural drainage existed.

Nothing of technical intelligence interest was found. A stock of ball bearings of the instrument type, was removed by F/Lt. Emery.

M. Dr. Ing. Hans Hyman und Co. Forschungs Institut at Nieder Ramstadt.

F/Lt. Bickerdike and Dr. Butler visited this vibration research laboratory hoping to find samples of vibration-packed metals or other material such as were described by Dr. Hyman, during his interview at Kitzingen.

Dr. Thurnau, the man in charge of the laboratory lives at Nieder Ramstadt, but was not available at the time of the visit. Herr Hüttmann, a foreman, was on the premises and demonstrated some of the apparatus.

The building was not badly damaged, and most of the equipment appeared to be in running order. The laboratory contained a number of vibrating platforms for shaking, and two vibrating presses. The former were operated mechanically by means of eccentrics or unbalanced flywheels, and the latter by alternating-current electromagnets. There was no evidence of supersonic work. Experiments on the settling and separation of powders and the production of emulsions had obviously been carried out. A tin of explosive powder, some flour and a small stock if iron powder were found on the premises. The latter consisted of electrolytic powder obtained from a firm at Ettlingen, near Karlsruhe. A few weeks before the village fell into Allied hands, experiments were started on the production of sintered iron bullets by vibration pressing. Only three pressings were made, however, and they all failed. If the compacts had been sound, they would have been sintered at Ettlingen and the process worked out there on a commercial scale.

Evidence there did not seem to warrant further investigation without the presence of Dr. Thurnau or Dr. Hyman.

N. Home of Dipl. Ing. Helmut Keil, Buchen.

During the interrogation of this fellow at Kitzingen it was found that Keil had systematically been stealing new experimental vacuum tubes from the BHF instead of delivering them to Dr. Wesch at Messelhausen as he was supposed to have done. These tubes he said were hidden at his home.

Accordingly, Mr. Hausz accompanied Keil to his home and obtained the tubes. There were a number of samples of high-frequency triodes, magnetrons (low-power) for various frequencies, and one specimen said to be a very new type of magnetron, which is as yet unidentified. These tubes and Keil's story have been turned over to Major Dobbson, Royal Signals, leader of CAFT Group 1.

NOTE: The last three items are only indirectly connected with the activities of the Darmstadt Technische Hochschule but were included in this report for the sake of completeness.

R.W. PORTER,
7 May, 1945.

PROFESSOR VIEWEG - 8-9 May 1945.

During early firing tests of the A-4 rocket, the radio gear frequently failed to operate satisfactorily. It was thought that the failure might have been caused by the building up of an electrostatic charge on the rocket. The problem was referred to Dr. Vieweg because his laboratory was in a good position to carry out electrostatic experiments. The electrostatic work was related to the work on resins, according to Dr. Vieweg, because of the necessity for very pure insulating materials, and because of a similarity in measurement techniques.

One of Dr. Vieweg's assistants, Dr. Klingelhoffer did some theoretical work on the charge which a body might attain while moving through the atmosphere, taking into account such factors as dust particles, clouds of water droplets or ice crystals, ions, and the like, and on the way in which the jet would affect the charge. Experiments were carried out in the laboratory using small particles of resins such as polystyrol at relatively low impact speeds. The effect of the flame was studied in small combustion chambers under controlled conditions. Some tests were even made in freezing chambers to study the effect of ice formation. Tests on a larger scale were made at Peenemunde using large rocket motors with different fuels, and some attempts were made to study the friction effects in the super-sonic wind tunnel. These latter were unsuccessful because the impurity of the air made the results inconsistant.

As a results of this work, Klingelhoffer concluded that the maximum potential which might be expected of the A-4 would be less than 10,000 volts a value which would probably not cause trouble. Dr. Vieweg's opinion is that faulty manufacture and design of the radio components was probably the cause of the early failures, rather than any trouble due to electrostatic charge. The only means of protecting the rocket against electrostatic charges is the installation at the extremities of needles, similar to those used in aircraft.

No work was done by Klingelhoffer on other than the electrostatic phase of the problem. Calculations of measurements of the propagation of radio waves through the ionized gases in the jet were made by Prof. Dr. Wollmann of Dresden. Dr. Vieweg knew him but does not know the results of these experiments.

The work on the electrostatic charge on the A-4 was extended to include aircraft as well, and led to the suggestion by Dr. Vieweg of an electrostatic type of proximity fuse for flak rockets. This, device depended on the assumption that all aircraft would carry some electric charge even though every attempt was made to keep this charge as small as possible. The projectile was to have an insulated nose connected to electronic amplifiers in such a way that whenever the potential difference between the nose and the rest of the projectile charged rapidly, the charge would be exploded. Such a rapid charge in potential was expected to occur as the projectile approached any sort of a charged body. Tests were made by flying Ju.88's over the roof at Darmstadt, and using gliders; a sensitivity of about 20 meters seemed to be possible. Experimental firings at wire nets were made at Rechlin in February which showed at least a measure of success. It was hoped to have the design ready for production by the middle of 1945.

A part of Klingelhoffer's experimental program was the measurement of ion density in the atmosphere up to 2 km by means of a small recording electroscope mounted in a glider. It was arranged so that a condenser was discharged by ion conduction to a predetermined lower limit and then automatically recharged. The time of discharge was recorded and gave a measure of the ionisation present.

Also of interest to Dr. Klinselhoffer was the work of Dr. Yeorgi and Dr. Rossmann who measured the electric field of the atmosphere up to 10 km, using a device called a "Feldmuhle" developed by Prof. Schwerkhagen of Danzig and Dr. Luder of the Flugfunk Forschungsanstalt at Oberpfaffenhofen. Some of these instruments, as well as some of Prof. Viewegs ionization tubes might be found at Ainring or at Oberpfaffenhofen.

Prof. Vieweg was asked about the tests which were supposedly run under Steinhoff's direction at the DFL tunnel at Griesheim on the effect of E.Sl fields upon air flow. He proposed not to know Rushti who is supposed to have written a report on the subject, but said he believed Rossmann at Ainring, or his chief Dr. Hohendorf, would know about it. He went on to mention that Steinhof was an enthusiastic glider pilot, and had a number of interests at Griesheim and at Ainring.

Dr. Vieweg was also asked about Hildebrand's work on the Behaltermesser (liquid lead indicator). He described it as follows: An insulated plate is mounted in the top of the container and an insulated lead brought out. The capacitance between the plate and the rest of the container depends on the quantity of liquid remaining. The valve of this capacity is measured by a self-balancing bridge device furnished by Siemens. Hildebrand's work was to supply the correct material and design for the insulated plate and container, and to correct a few difficulties in the bridge amplifier. These problems were solved successfully, according to Dr. Vieweg, and all samples were sent to Peenemunde.

The artificial rubber material obtained from Dr. Hildebrand's laboratory, said to have been used in pressure and flow indicators for acid and alcohol, was probably Opanol, trade name for iso-butanol.

Interrogation of Prof. Buchhold and Prof. Walther. 9 May 1945, London.

Profs. Buchhold and Walther were interrogated together about the method of range control using a stabilized platform and two accelerometers. Prof. Walther agreed to write a short discussion on the mathematical basis for this scheme.

Prof. Buchhold said the system was not used because it was complicated and bulky, as well as heavy, and that as an alternative, a method for controlling the thrust was being considered. This would have used an axial accelerometer which would operate a polarized relay whenever the thrust became greater or less than the desired value. This relay, in turn, would operate a motor-driven valve in the H_2O_2 line to the combustion chamber for the turbine. It was expected that a "Rückführung" device of some sort would be necessary to prevent hunting because of the long time constants involved in the central loop.

A second question asked Prof. Buchhold was the "stiffness" of the feedback loop in his integration accelerometer. He was not at all certain of this but the following data seems about right: An acceleration of 1 g produces a motion of about $\frac{1}{2}$ degree which causes a current of 2.5 ma to flow into the coils. The torque produced by this acceleration (which is exactly balanced by the electrical torque) is about 2.5 g cm.

Prof. Buchhold added that if the system were mucg stiffer than this it would oscillate. In production it was hard to keep the amplification constant, so an anti-hunt circuit was used, which consisted of a capacitor and resistance in series, connected across the dc terminals of the copper-oxide rectifier. By choosing the right values, hunting could be effectively eliminated for any amplifications possible with one tube.

R. M. PORTER.

USFET
Office, Chief Ordnance Officer
RESEARCH & INTELLIGENCE BRANCH
APO 413

ORDNANCE TARGET REPORT 129

Target Investigation - Electromechanische Werke
Garmisch-Partenkirchen

Target No: 4/149

Subjects Covered in Investigation:

Control of the "Wasserfall"

Suggested Distribution:

Ordcit Project
B.T.L. Project
Hermes Project (2 copies)
Bumblebee Project

Report by

Dr. R. W. Porter
Technical Investigator

CONTROL OF THE "WASSERFALL"

Investigators:

F/Lt. Stokes, RAF
S/L. Sharpe, RAF
C. H. Smith, U. S. Navy
Lt. (jg) Wilkinson, U. S. Navy
R. W. Porter, U. S. A. Ordnance

I Introduction:

"Wasserfall" is the code name for the C 2, a relatively large supersonic anti-aircraft missile developed by the Electromechanische Werke, formerly known as H A P 11, under the technical direction of Dr. von Braun and under the military direction of Obs. Lt. Dr. Halder. The electrical control equipment was developed by a group known as E W 224 headed by Dr. Theodore Netzer of Dr. Steinhoff's section. Members of this group who were interrogated at Garmisch-Partenkirchen were Dr. Netzer, Dr. Elfers, Dr. Geissler, Dr. Haft, Dr. Weiss, Dr. David, Dipl. Ing. Walter, Dipl. Ing. Klein and Ing. Nicklas.

Four different models of the Wasserfall have been identified. The first W 1, had aluminum tanks for the propellants; only one or two of these were ever assembled. The second model, W 2, had a shorter wing and tail surface span and used steel tanks for the propellants. Hydraulic rudder servomotors made by L G W were incorporated. About five of these rockets were constructed, of which only two or three were fired. In the third model, the W 3, the aerodynamic shape was retained, but the interior fittings were changed slightly and a standard K 12 electro hydraulic servomotor was adopted. About forty of these were made. It is reported that thirty-five were fired using the K 12 and five were modified to use an all-electric servomotor. Of these latter only the one was successfull. The latest design, the W 4, was to use a simplified hydraulic servomotor designed and built by L G W, and again had slightly different interior arrangements. It is believed that no samples to this design were completed. The following data therefore refers primarily to the W 3.

No firings were ever made against a target nor were any of the computing or target-seeking devices which will be described in this report ever tested in actual firing trials. The test engineers were generally pleased if the rocket could be made to fly stably and to respond properly to simple control signals sent from the ground. It is also interesting to note that some of the early tests of control equipment for the Wasserfall were made using A 4 rockets. Dr. Steinhoff said that the now famous "Swedish Incident" was the result of such an experiment.

II General Characteristics of the Missile:

The C 2 is intended to carry a 300 Kg warhead; its weight at launching is 3540 Kg and its weight at target is 1610 Kg, giving a ratio of initial to all burned weight of approximately 2.2. Launching is vertical with a thrust of 8000 Kg which results in an acceleration of about 2 1/4 g at the start and a maximum acceleration of 4.95 g at the end of burning. The total impulse is said to be 360 000 Kg sec, which means that the specific impulse must be approximately 186. Maximum burning time is about 45 seconds. Salbei and Visol are used as propellants and are injected into the combusion chamber by means of compressed air carried in a large spherical bottle just behind the war head.

The total length of the missile is 783 cm. and the diameter 88 cm. Four swept-back wings having a span of 189 cm are used in addition to four tail fins with relatively large control surfaces or rudders. Fig. 1 shows a rough sketch of the arrangement of the wings and control surfaces. These wings make it possible to obtain a maximum lateral acceleration of the order of 12 g for supersonic velocities at the maximum angle of attack of about eight degrees. It was planned that the Wasserfall should have a maximum velocity of 800 meters per second, but the highest velocity actually obtained is only about 600 meters per second.

The principal control of the missile during flight is obtained by the action of the aerodynamic control surfaces. The design of the missile and of these control surfaces is such that the center of pressure on the surfaces varies only a few millimeters over the range from subsonic to supersonic velocities; consequently it has been possible to balance the control surfaces very carefully and obtain a relatively small value of control torque to be supplied by the rudder servomotors. Until the missile has attained sufficient velocity to make the aerodynamic controls effective, control is obtained by means of rectangular vanes in the jet. These vanes are either jettisonned by explosive bolts after about twelve seconds of flight, or are made of a hard wood, such as oak, which will burn away gradually at the proper time.

III <u>Launching</u>:

The rocket is launched vertically from a stationary platform of tubular construction, arranged with wheels so as to be easily transportable to and from the site. It is not necessary to turn the launching platform so that the "bottom" of the rocket faces toward the target; the control system is symmetrical and the rocket can be sent in an desired direction after launching. However, the rocket must be oriented roughly with respect to geographical coordinates in order to simplify the problem of correlating the two lateral axes of the missile with the two axes of the control device.

IV <u>Trajectory</u>:

The trajectory normally consists of three parts. The first is a straight vertical path which lasts for six seconds during which the rocket is controlled only by means of its internal gyro system. At the end of this period it will have acquired a velocity of approximately 120 meters per second and a height of about 360 meters. The second part of the trajectory is a transition curve designed to bring the missile as quickly as possible into the line of sight. During this period it is controlled by an operator on the ground who acts in accordance with information from a computing device called the "Einlink-Rechner". The instantaneous positions of the rocket and of the target are measured either by optical or radar means. During the third part of the trajectory the control is simple line-of-sight control, that is the operator attempts to maneuver the rocket in such a way that it will always lie on a line between the target and the control point.

If the line-of-sight path could be followed accurately enough, it would end in a collision with the target or a near miss. Since it is questionable whether sufficient accuracy can be obtained by this method, however, several homing or self-seeking systems of control have been proposed which will be described later. Because the effective range of such devices is limited, the missile would be launched and controlled as outlined above until close enough for the homing device to detect the target. The trajectory would then enter a fourth phase during which control from the ground would cease and the homing device would guide the missile to the target. One of several types of proximity fuses which were under development was to be used to explode the war head whenever the missile came within lethal range of the target.

The velocity of the rocket reaches a value equal to the speed of sound about seventeen seconds after launching. Shortly before this point some difficulty has been observed with control instability but this critical region is quickly passed over so the trouble does not appear to be serious. The thrust ends about forty-five seconds after the start, but the velocity remains supersonic until seventy to eighty seconds and control is generally effective until ninety seconds after the start.

The term "Treffbereich" is used by the Germans to describe a surface inclosing the volume in which an aircraft must be located at the instant of collision if a hit is to be obtained. Curves of the "Treffberich" for "Wasserfall" are shown in Fig. 2. If it is assumed that no evasive action is taken by the target and that the target velocity is 150 meters per second in the outward direction, the maximum height is about 18 Km and maximum slant range about 28 Km. For constant evasive action of 2 g by the target, the maximum height is reduced to about 15 Km and the maximum range to about 24 Km.

V Ground Control Apparatus:

The information-flow diagram shown in Fig. 3 is believed to represent the basic control system planned for the Wasserfall, although it must be realized that no complete system of this kind has ever been tested and that consequently disagreement exists among the various individuals working on the project as to what will work and what will not.

Two standard flak-control radar sets of the Mannheim type are used for determining the instantaneous present positions of the target and of the rocket, respectively. Because these sets cannot be located close together without mutual interference, a parallax computer must be used to convert the data from one system of coordinates to the other. Such computing devices are well known. The difference in azimuth angle or preferably the slant-plane angle between the rocket and the target is presented on the horizontal plates (of a large cathode-ray oscilloscope) and the difference in elevation angle is presented on the vertical plates, cuasing the spot to move in such a way as to indicate the angular position of the rocket with respect to the line of sight.

During the transition period when the rocket must be guided from its vertical path into the line of sight, a second spot is shown on the indicator which gives an artificial elevation position for the rocket, displaced from the real position in elevation by an amount equal to the displacement of the theoretical transition path from the line of sight. Thus it is only necessary for the operator to keep this second spot in the center of the tube in order to guide the rocket smoothly into the required trajectory. The displacement of the second spot is computed by a computing element called the "Einlink-Rechner", sometimes referred to as "Gummiband". It consists basically of two integrators arranged in series so that the input is equal to the second derivative of the output. By means of this device the difference angle is brought to zero as quickly as possible without exceeding a maximum arbitrary value of angular acceleration.

Since the rocket is not fired from a rotatable platform, the relation between the control surfaces and the vertical will depend on the azimuth angle, or in other words, the bearing of the target with respect to the launching point. Furthermore, depending on the nature of the trajectory, the relation of the control surfaces to the vertical may change during flight, even though the missile is perfectly stabilized in roll by means of the gyroscopic control. A third computing element called the "Tau-Rechner" keeps track of this angular relationship between the control axes and the vertical. The motion of the control stick is resolved in such a way as to send the proper signal to each pair of control surfaces so that whenever the operator moves the stick forward or backward the rocket will turn in a vertical plane and whenever he moves it sideward the rocket will turn in the slant plane. This resolution can be accomplished in several ways, the simplest being a rotation of the base of the control-stick assembly with respect to the operator. It is necessary, of course, that the rocket be set up in a known position, the same each time, and that the operator be correctly positioned with respect to the reference of the control stick assembly.

Disadvantages of this control system are obvious. For example, the scale of the C R T display is constantly changing unless some correction is made to allow for change in range. Furthermore the conditions of control are also varying continuously because of the changing speed of the rocket, changing atmospheric conditions, the fact that the control vanes in the jet are either burned off or jettisoned during the early part of the flight and the fact that control must be maintained after the thrust ceases. Dipl. Ing. Walter had been given the problem of designing a device to go between the control stick and the ground transmitter which would vary the control sensitivity as an arbitrary function of time. However the design had not been completed, and the conditions for which it was to have been designed had not been definitely stated. Another undecided question was whether or not to include a term in the control fuction which would be proportional to rate of motion of the control stick. Such an arrangement would be similar to the aided-laying systems commonly used in manually operated fire-control devices and the like. Although opinion generally seemed to be against its use, the rate term was being tested on model systems at the time work was interrupted.

VI Radio Control:

It was proposed to use standard Würzberg or Mannheim flak-control radar sets for obtaining the instantaneous present-position data on the target and rocket. These systems are well known, having been covered by several previous reports; no further description will be included here. It is interesting to note, however, that Dr. Netzer believed that the accuracy attainable with the "Mannheim" when not jammed with "window" or other counter measures was about 1/10 degree. Efforts were continually being made to improve the operation of these radar sets against jamming. Microwave radar development had not yet reached a stage of development in Germany such that it could be considered as an immediate possibility.

The signalling system used for the firing tests, was a modified version of the "Kachl-Strasbourg" or "Kachlgerät" which is also used in the HS 293, FX 1400, "Enzian", and others. Two pairs of audio-frequency tones are employed, corresponding to the two pairs of rudders. One pair is 8000 and 12000 cups, and the other is 1000 and 1500 cps. Each pair of tones is keyed at a rate between 20 and 25 cycles per second in the manner of "mark-space" keying. A fifty per cent keying ratio corresponds to no control signal; one-hundred per cent of one tone gives rise to a maximum rate of turn in one direction and one-hundred per cent of the other tone represents maximum rate of turn in the other direction. Intermediate ratios provide variable rates of turn. The keying is produced by a motor-driven cam, the position of which can be varied by means of the control stick.

The modulating oscillators and the transmitter are the same as those used for the Kachlgerät. Any one of 18 frequency channels may be selected, all of which are in the 50 mc region. A simple dipole aerial is used. The receiver also is identical with that used in the "Kachlgerät". It consists of four parts: an rf amplifier and mixer, a local oscillator with afc, an if amplifier and diode detector with a v c, and an audio-frequency discriminator, or decoder. In the decoder the four modulation frequencies are separated by filters, rectified, and amplified used to operate two polarized single-pole double-throw relays. These two relays will therefore be alternately energised and deenergised at a frequency of about twenty cycles per second and with a keying ratio which is the same as that of the transmitted signals. A fixed d-c potential is keyed by these relays and then filtered so that smooth d-c signals are produced having direction and amplitude corresponding to the "mark-space" ratio of the transmitted signals and therefore, also to the motion of the control stick. The receiving aerial on the rocket consists of metal strips mounted on insulated portions of the trailing edges of the rudders. Their appearance and functioning is similar to that of the trailing edge aerials on the A 4.

A new radio system for control of missiles such as the "Wasserfall" was being developed by Telefunken, most of the work being done at Hohenpeissenberg. This new system, known as the "Brigg-Kogge Verfahren", or sometimes as "Kran-Brigg" uses the same control scheme as the "Kachlgerät", but operates on a frequency of 1300 to 1500 megacycles (20 to 23 cm). At this higher frequency, directional transmitting and receiving aerials can be used, thus reducing the possibility of jamming. For example, the transmitting aerial consists of a dipole with a parabolic reflector which is intended to be mounted on the radar set which is used to track the rocket. This arrangement allows a very narrow beam to be used and consequently permits the use of a low sensitivity receiver. A directional receiving aerial is also contemplated, bu the design has not yet been worked out.

The most important considerations in the design of the "Brigg-Kogge" were low cost and reduction in the number of critical components such as vacuum tubes. There were at least two models of the transmitter ("Kran") one of which was crystal-controlled and used three tubes, and the other of which was a cavity oscillator with only one tube, the frequency being held constant by ingenious mechanical design. A super-regenerative receiver was to be used on the rocket. Further details on this system will be found in reports on the interrogation of Dr. Leo Brandt and Dr. Paul Kotowski, Telefunken engineers, at Munich.

For testing purposes a telemetering system known as "Messina I" was used to transmit continuously such information as pressures, temperatures, rudder positions, gyroscope positions, and the like. "Messina I" is described in detail in a report by W. Hausz dated May 23 on the interrogation of Dr. Gröttrup.

VII <u>On-Board Control Apparatus</u>:

Stabilization was accomplished by the use of three gyroscopes arranged in gimbal suspensions as shown in Fig. 4. Standard aircraft auto-pilot gyroscopes manufactured by L. G. W. in Berlin were used in all three positions. These were mounted in the tail section just behind the forward bulkhead. Potentiometer-type pickoff devices were used, the stators of which were arranged so that they could be turned by tiny motors. These motors were specially designed for the purpose by L. G. W.; the speed of rotation is accurately proportional to the applied voltage and the power required is very small.

Fig. 5 shows how the gyroscope is used to control the missile. Operation is briefly as follows: The gyroscopes are caged until the instant of launching whereupon they are released and remain free for the rest of the flight. During the initial vertical portion of the trajectory there is no external control; if the axis of the missile becomes inclined, one or both of the pickoff brushes will be displaced and a potential difference will be applied to the input of the control amplifier or "Mischgerät", which in turn causes an unbalanced current to flow in the control coils of the rudder servo. The resulting motion of the rudder produces a torque on the missile in such a direction as to reduce the inclination.

At the end of the initial six-second period, radio control is established. If the operator then moves his control stick forward, the keying ratio of the transmitted signals is changed as described above, so that a proportional d-c potential is produced at the output of the "decoder". This voltage is used to run the motor which turns the stator of the gyro pick-off. As the stator turns, the rudder servo are brought into operation until the missile has turned through the same angle as the stator, the gyro axis meanwhile remaining fixed in space.

Thus to a first approximation, motion of the control stick produces a proportional rate of turn of the missile. The local system including the missile is dynamically stabilized by the usual R-C equalizer circuits and by position feed-back from the rudder servomotors. The control of both pairs of rudders is exactly the same, naturally enough, since a given pair may be either vertical, horizontal, or at any angle in between. The names "vertical" and "lateral" control are used only for purposes of discussion. All four rudders are used for roll stabilization, operating differentially in pairs.

The A-4 "Mischgerät" or control amplifier was adopted because it was readily available. It had to be modified, of course, because of the difference in the way roll stabilization was applied. It is believed that the equalizer circuits were also changed because of the different physical characteristics and natural periods of the "Wasserfall". The exact values used are not known.

Because of the bottleneck in tubes, experiments were being made with magnetic amplifiers. A standard unit designed for use with the automatic pilot of the Me109 and other fighter aircraft was tested in a model system of the rudder control. This unit requires an input of 1 to 2 milliamperes into 400 ohms to produce a saturated output of 100 to 200 milliamperes. The time constant is about 100 milliseconds; it can be reduced to as low as 8 to 10 milliseconds, but only if the input power is increased in proportion. Results of the tests were unsatisfactory because of the long time constant of the magnetic amplifier as compared with that of an electronic amplifier. The time constant is particularly important in the "Wasserfall" because of its high natural frequency (aerodynamic) with is of the order of 3 cps for lateral motion and much higher for roll. Dr. Klein was personally in favor of the magnetic amplifiers and thinks he could have overcome the time-constant trouble. However, the scarcity of mu-metal presented additional difficulties and the twenty to forty man-hours of labour required per amplifier was considered excessive in view of the fact that four amplifiers were required for each rocket.

Originally it was intended that the A-4 rudder servomotors would be used, but they proved to be too weak and too slow to handle the large rudders of the C-2 quickly enough to maintain stability. An aircraft automatic pilot servomotor known as the K 12, built by L. G. W. for the Ju 88 and other military craft, proved to be satisfactory except that it cost too much. Most of the test flights were made using the K-12.

In an effort to find something less expensive, Ing. Nicklas was experimenting with an electric servo which consisted of a 600 to 800 watt electric motor with a three-stage reduction gear, directly controlled by relays. To keep this system from hunting, the relays are caused to "chatter" or pulse at a frequency determined by the time constants of the relays themselves. This pulsing is produced by a feed-back circuit and gives a control which is similar to proportional control. This scheme was tried in the air about five times, at least one of which was considered successful by Dr. Elfers.

Another scheme which was included in some of the designs was a very simple hydraulic device consisting of a double-acting piston and electromagnetically operated valves. Oil pressure was to be obtained either from a separate compressed air bottle or from the main air supply which was used to pressurize the propellant tanks. Only enough oil was used to last seventy to ninety seconds under normal operating conditions; the oil was discharged after use since no sump was provided.

It is apparent that any system in which the control is obtained by rotating the gyro pickoff stators will be limited in the angle through which it can turn without the gyro "freezing", that is without the axis of the gyro becoming alignod with tho axis of tho gimbal. In a missilo of this kind which may turn in any direction, horizontal flight cannot be attained without loss of control no matter how the various gyroscopes are oriented. A system in which the missile is turned by precessing the gyroscopes is not subject to this difficulty because the gyro axes can be maintained approximately in a fixed relation to the axes of the missile. This fact was pointed out to certain of the E. W. engineers during interrogation and they were asked why the former arrangement was used. The answer was that the L. G. W. gyros were readily available whereas other gyros with torque motors were not. Some work was being done, however, on a completely new control system using restrained or rate gyros together with the above-mentioned magnetic amplifier and electric servo motor. No further details on this system are known.

VIII Model Experiments:

Because of the difficulties and expense involved in testing control apparatus in actual rocket flights, it is of the greatest importance to be able to simulate flight conditions in the laboratory by means of electrical or mechanical models. The simplest device of this kind was designed and built at the Darmstadt Technische Hochschule by Dr. Häussermann under the direction of Prof. Vieweg. It consisted of a pendulum with variable damping and natural period, having an electric torque motor for excitation and means for measurement of the position. By properly adjusting the pendulum, one can simulate a missile having any combination of aerodynamic moment, damping, and inertia, and by varying the input to the torque motor one can give the effect of rudders of different sizes, different velocities and so on. It is therefore possible to test any proposed servo system for dynamic stability, sensitivity and so on, under all expected flight conditions before it is actually installed in a rocket.

A somewhat more complicated model is a completely electrical system developed by Dr. David of E. W. A typical system, such as that shown in Fig. 6b is based on the following equations:

$$\ddot{\alpha} = -a\dot{\alpha} - b\alpha + c\left[x - (\theta + \alpha) + d\dot{x}\right] \qquad (1)$$

$$\dot{x} = e\,k \qquad (2)$$

$$\dot{\theta} = f\alpha + g \sin \textcircled{H} \qquad (3)$$

where $\textcircled{H}$ is the angle of the tangent to the theoretical trajectory.

$$\dot{z} = \nu\,\Delta\theta \qquad (4)$$

where $\Delta\theta = \theta - \textcircled{H}$ (5)

$$\varepsilon = \frac{z \cos(\textcircled{H} - \gamma)}{\gamma} \qquad (6)$$

In the above equations, α, θ, $\textcircled{H}$, $\Delta\theta$, γ, are angles illustrated in Fig. 6a, a, b, c, d, e, f, g, v, and r are physical constants which vary with time in a known way for any given trajectory, Z is the linear error at right angles to the trajectory, and ε is the angular error measured at the control point. This error is displayed to an operator who responds by moving a control handle which changes the control signal K. In this way the overall system stability, including the reaction characteristics of the operator can be studied.

Equation (1) can be rewritten as follows:

$$\ddot{\alpha} = -A\dot{\alpha} + B\left[-\alpha + C\int_0^t (\dot{x} - \dot{\theta})\,dt + D\dot{X}\right] \qquad (1a)$$

This is the form actually used since $\dot{X}$ and $\dot{\theta}$ are immediately available and can be integrated together. It will be seen that upon substitution of (3) in (1a) a fourth-order differential equation in α is obtained. Four integrators are required for its solution; a fifth integrator is needed to determine θ, and a sixth to determine Z.

The basic integrator circuit used in this machine is shown in Fig.7. The value to be integrated is fed into the first tube as an a-c signal. It is amplified, rectified and the resulting d-c voltage which is of rather large magnitude is connected across a series resistor and capacitor. If the product of R and C is very large, the resulting voltage across the condenser will approximate the value of the desired integral. This voltage is turned into a c by means of a modulator circuit, and is again amplified and connected to the output. Part of the output voltage is coupled back into the input in such a way as to compensate for the finite time constant of the R-C circuit. In this way a very accurate integration can be obtained. Over a period of 15 seconds, Dr. David believes, any reasonable function can be integrated with an error no greater than one percent.

The most elaborate model is one designed by Dr. Fischel of the Deutsche Forschungsanstalt für Segelflug Ernst Udet. This machine was in construction in a village called Teisendorf near Ainring airport. Dr. Fischel's system includes a 5000 to 1 scale model of the flak missile problem which requires a room about 20 by 40 feet and 20 feet high. The missile is carried on a device similar to a Gantry crane which moves along the length of the room. A horizontal cross wire is made to go up and down and a point representing the missile is moved along this wire in such a way that motion in three coordinates can be obtained. A target is provided which can also be given any desired motion in three coordinates.

The operator, who can see both the missile and the target, reacts by moving a control stick of the same type that would be used in service. The control signals are sent in the normal way to the on-board control apparatus which is mounted on a large gymbal suspension. The output of this control equipment is transmitted to computer "A" which, taking into account the inertia of the missile and the torques which act on it, determines the turning motion which would result. The gymbals are then rotated by means of small servomotors so that the control apparatus is always oriented in the same direction as if it were on the flying missile. From calculated direction of the missile, its speed and its aerodynamic characteristics, computer "B" calculates the direction of the velocity vector, or in other words, the direction of the tangent to the trajectory. Computer "C" then multiplies the speed by the cosine angles of this direction vector and integrates the three resulting components to obtain the instantaneous position of the missile.

It should be noted that target-seeking systems could also be tested by the addition of another computing element since both the direction vector from the missile to the target and the direction of the missile axis are continuously available.

Although Dr. Fischel has operated the machine "qualitatively", that is without regard for the aerodynamic properties of the missile, the "quantitative" device described above is only partly complete and has never been tested.

IX Homing Devices:

Both radio and infra-red types of homing devices were being considered for eventual use in "Wasserfall", the infra-red projects being more numerous and nearer to completion. A report entitled "Development of Homing Devices as of 15 August 1944", obtained from the Sonderkommission Elektr. Zubehör zu Munition, lists many of the different systems which were under development. Dr. Weiss stated that although infra-red target-seeking systems using mirrors had been operated in the E. W. laboratories, no practical flight model had ever been completed. Most of the work was being done at Leitz and coordinated by Dr. Rosenthal.

For infra-red installations, the entire nose section was to be made of special iron-free flint glass of which several samples had been obtained. One sample was supplied by Prof. Kliefoth of Breslau. The infra-red properties were considered satsifactory; mechanical properties had not yet been tested. This nose section was to be 8 or 10 millimeters thick and would be either molded, blown or centrifugally cast. The maximum temperature which the nose would reach in flight was calculated to be about 200°C., which the glass could stand without difficulty.

The range of infra-red detection systems in general is one to twenty kilometers, depending on the angle included in the field of view. Specifications for "Wasserfall" required 3 Km range with a 6° field. Baron von Pfeifer who had a direct order from the Flak Kommando has developed a long-range infra-red device known as "Madrid" with a very small field, but which has a very clever scanning device which facilitates picking up the target.

Only two infra-red cells were available for this development; the Zeiss Ikon cell developed by Dr. Görlich and the Elektro-Akustik from the company by that name at Namslau. A. E. G. was also working on a cell, as were many others. The phosphor cells of Dr. Wesch were still, according to Dr. Weiss, "fighting for recognition".

Three types of scanning described by Dr. Weiss are illustrated in Fig.8. The simplest shutter is a disc with a round hole in it. The radiation from the target is focused so as to cover an area roughly the size of the hole. When the target is in the center, no modulation results; otherwise the amount and direction of the error (polar coordinates) is given by the percentage and the phase of the modulation with respect to a reference on the shutter disc. The same effect can be obtained without a shutter by placing the mir r or lens eccentrically with respect to the axis of the device and rotating it. In this case the phototube should have an aperture about the same size as the target image. If the target can be focused into a smaller image, the shutter shown in Fig. 8b is preferable. In this scheme the magnitude of the error is given by the ratio of light to dark time and the direction by the phase of the square-wave modulation. The third idea, shown in Fig. 8c, has the characteristic that when the image moves away from the center a frequency-modulated square wave is produced, the amplitude of the f m giving the magnitude and the phase of the f m giving the direction of the error. This last scheme is claimed by Dr. Weiss as his own development.

A radio homing system for Wasserfall was being developed by Blaupunkt in Berlin. It was to be a passive system, at least one variation being designed to home on our "Meddo" or "Rotterdam" airborne radar sets. Dr. Weiss had never seen this system, but mentioned that he had heard the term "Stiel Strahlen" (rod radiators) in connection with it. For the radio installations, glass, wood, or artificial resin nose sections were being considered.

The first and most difficult problem in the use of any homing system is that of bringing the rather narrow field of the homing device to bear on the target at the proper time. The two solutions which E. W. was considering were both based on the fact that the rocket is controlled during the initial part of its flight in such a way as to keep it on the line of sight from the control point to the target; therefore, the direction vector from rocket to target will be approximately the same as that from control point to target. The homing device can be brought to bear on the target by (a) transmitting the angular position of the line of sight by radio from the ground and measuring it off in the rocket with respect to a fixed coordinate system maintained by gyroscopes, or (b) using a receiverr on the rocket to D/F on the ground radar which is tracking the target.

After the homing device has picked up the target, its axis is held fixed in space by the gyroscopes and its error signal is used to steer the missile. As a result, the rocket will fly a constant bearing course until it collides with the target. Such a course is illustrated (in two coordinates only) in Fig. 9. The target is shown attempting to avoid the missile by making a turn at point 6. At point 7, the target is to the left of the axis of the homing device. The missile therefore turns to the left until at point 8 it has over corrected and finds the target to the right of the homing axis. If the control system is properly damped, the missile will settle down on a new course as shown, which will produce a collision at point 12. If no homing were used, the missile would follow the dashed line, crossing the path of the target nearly one second too soon.

The advantages of homing are so great that it seems certain, in spite of the additional cost and complication, that some form of homing would have been used on the "Wasserfall" as soon as possible.

X Tailpiece:

No part of the equipment described above has actually been seen by the writer. In fact, much of it never existed except on paper and in the minds of the designers who were interrogated. There was no way to insure that the facts obtained were true; it is certain that they were not complete. Nevertheless, the information is being passed along in the hope that it may serve as background for more detailed investigations of the C-2, and in the belief that some of the ideas may prove useful in our own developments.

R. W. PORTER
Technical Investigator

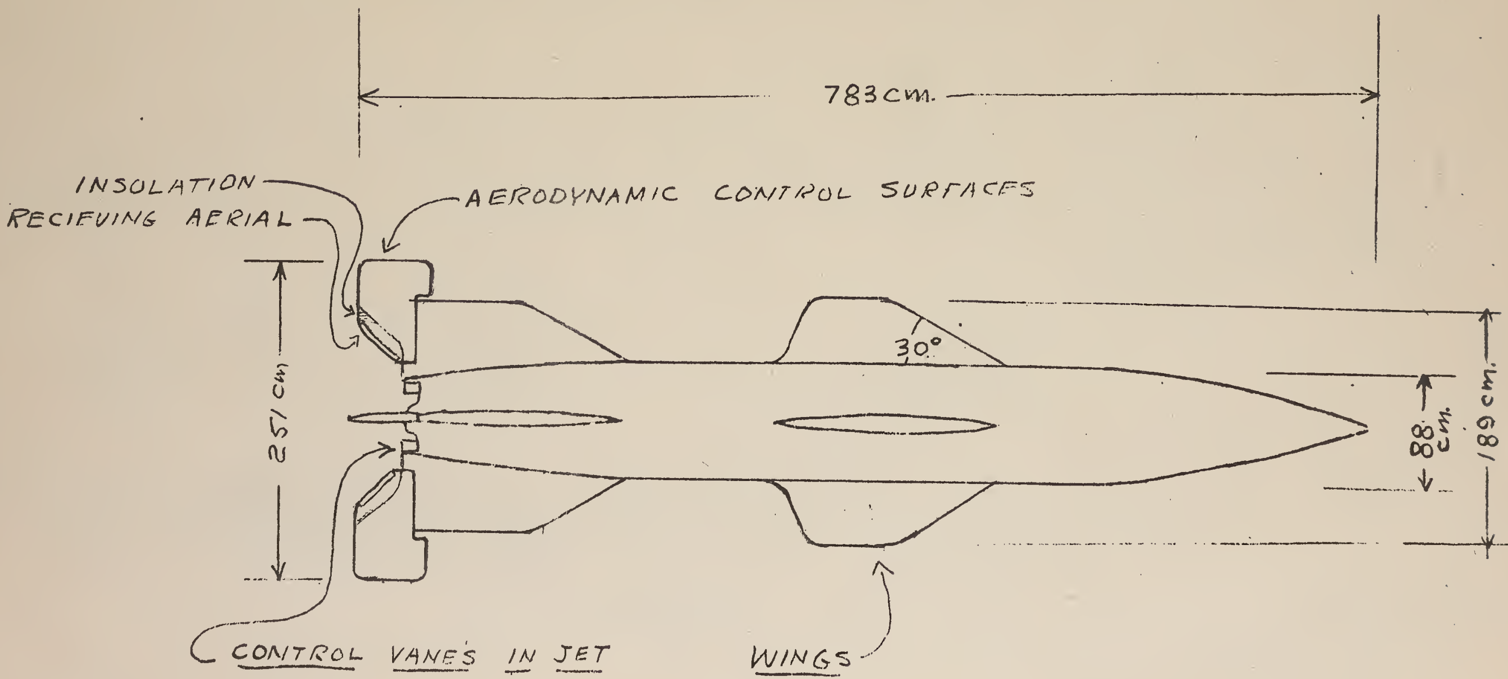


FIG. 1 ARRANGEMENT OF CONTROL SURFACES ON "WASSERFALL".

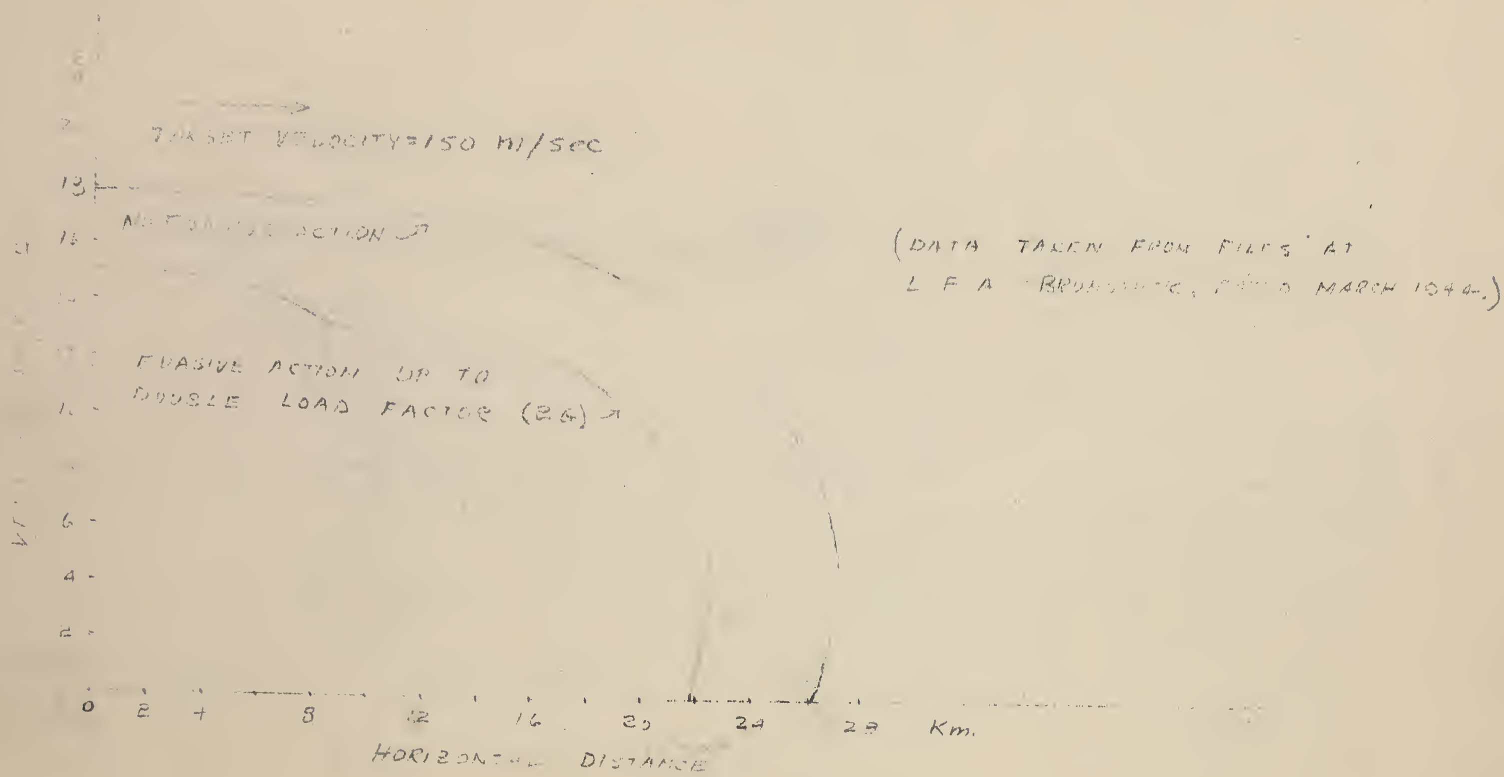


FIG. 2 "TREFFBEREICH"

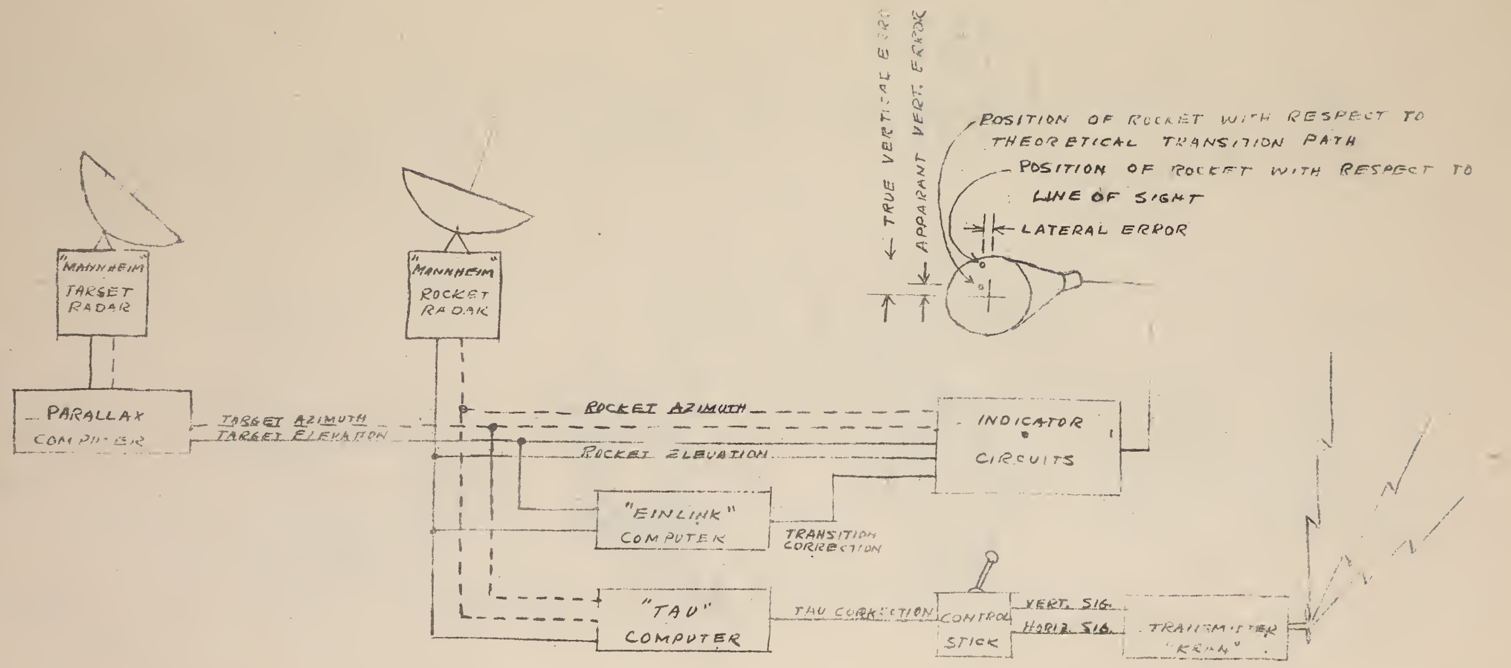


FIG. 3 SCHEMATIC OF PROPOSED GROUND EQUIPMENT FOR "WASSERFALL".

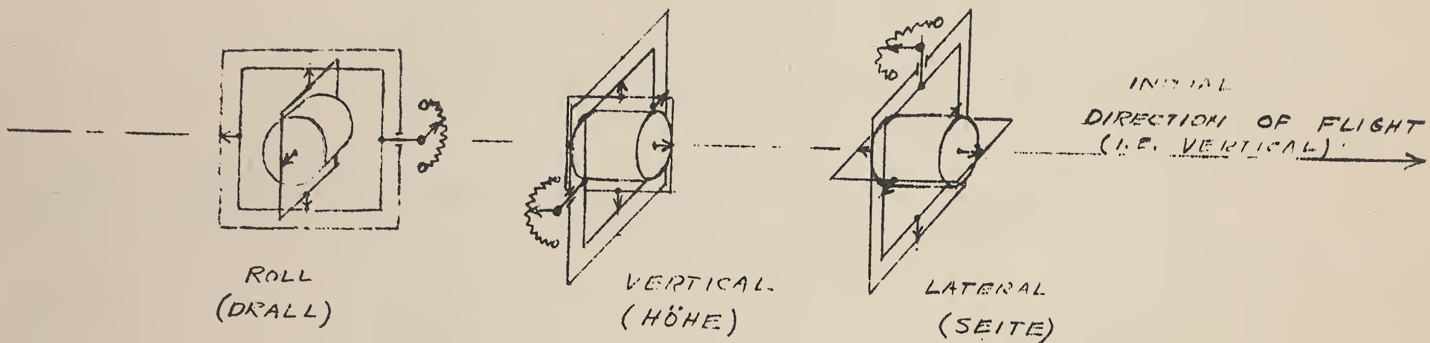


FIG. 4 ARRANGEMENT OF THE GYROSCOPES IN "WASSERFALL".

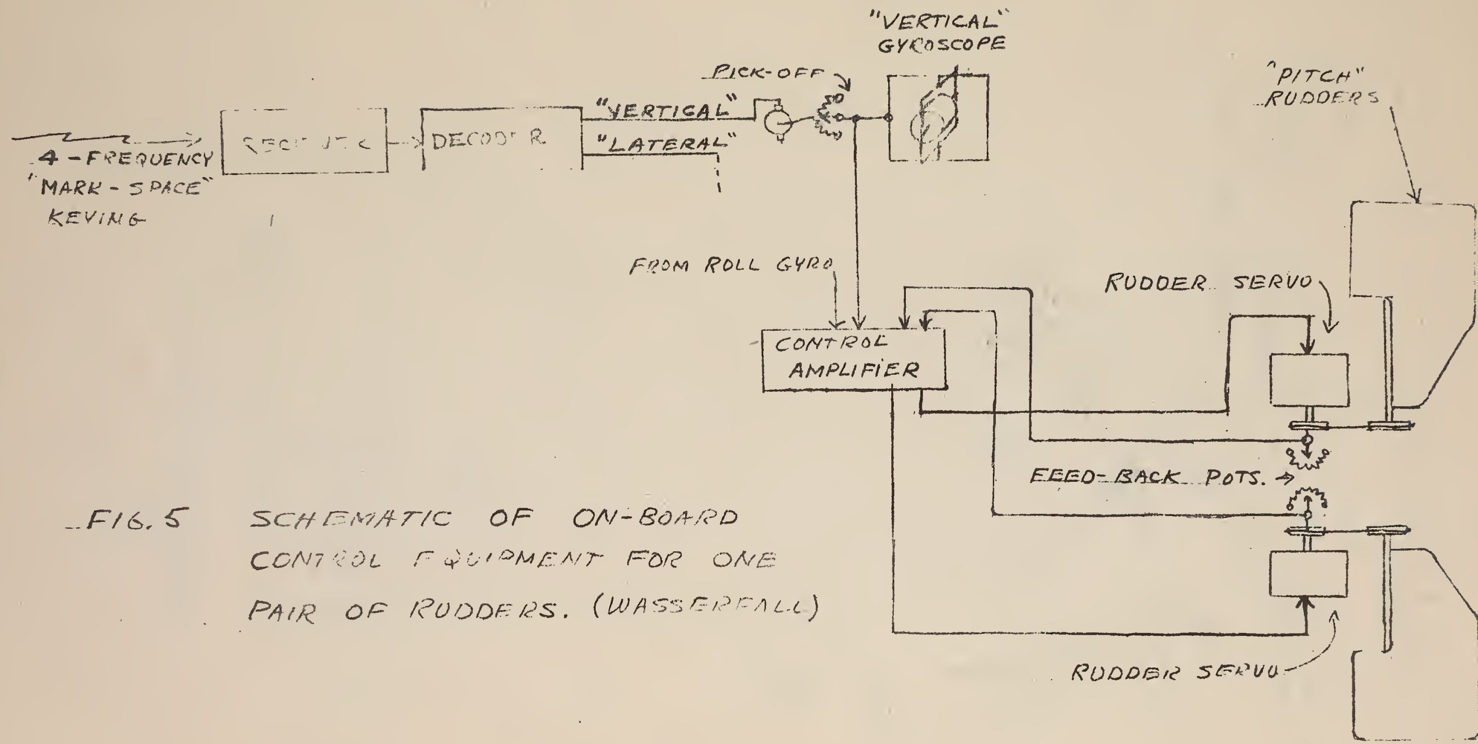


FIG. 5 SCHEMATIC OF ON-BOARD CONTROL EQUIPMENT FOR ONE PAIR OF RUDDERS. (WASSERFALL)

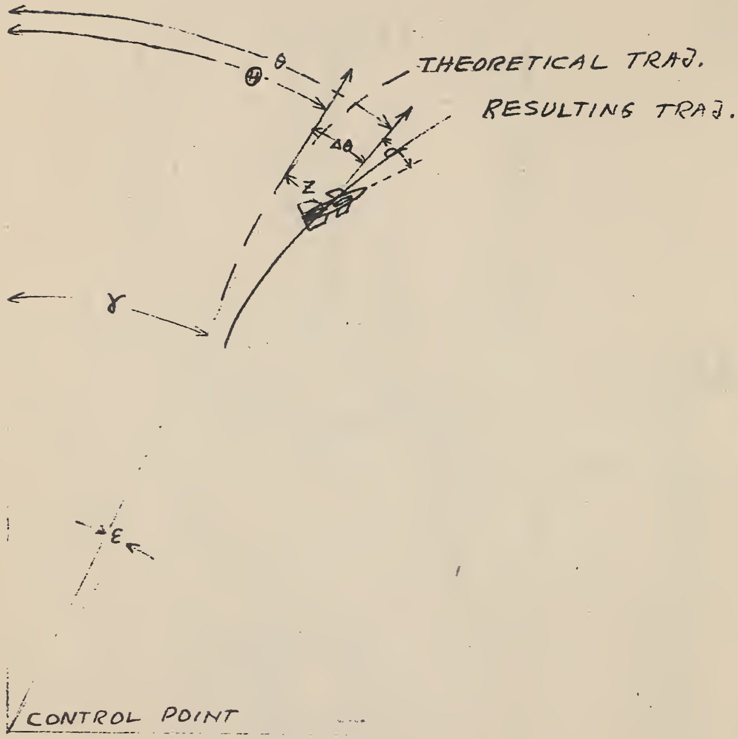


FIG. 6a. ANGLES REFERRED TO IN EQUATIONS FOR DR. DAVID'S MODEL

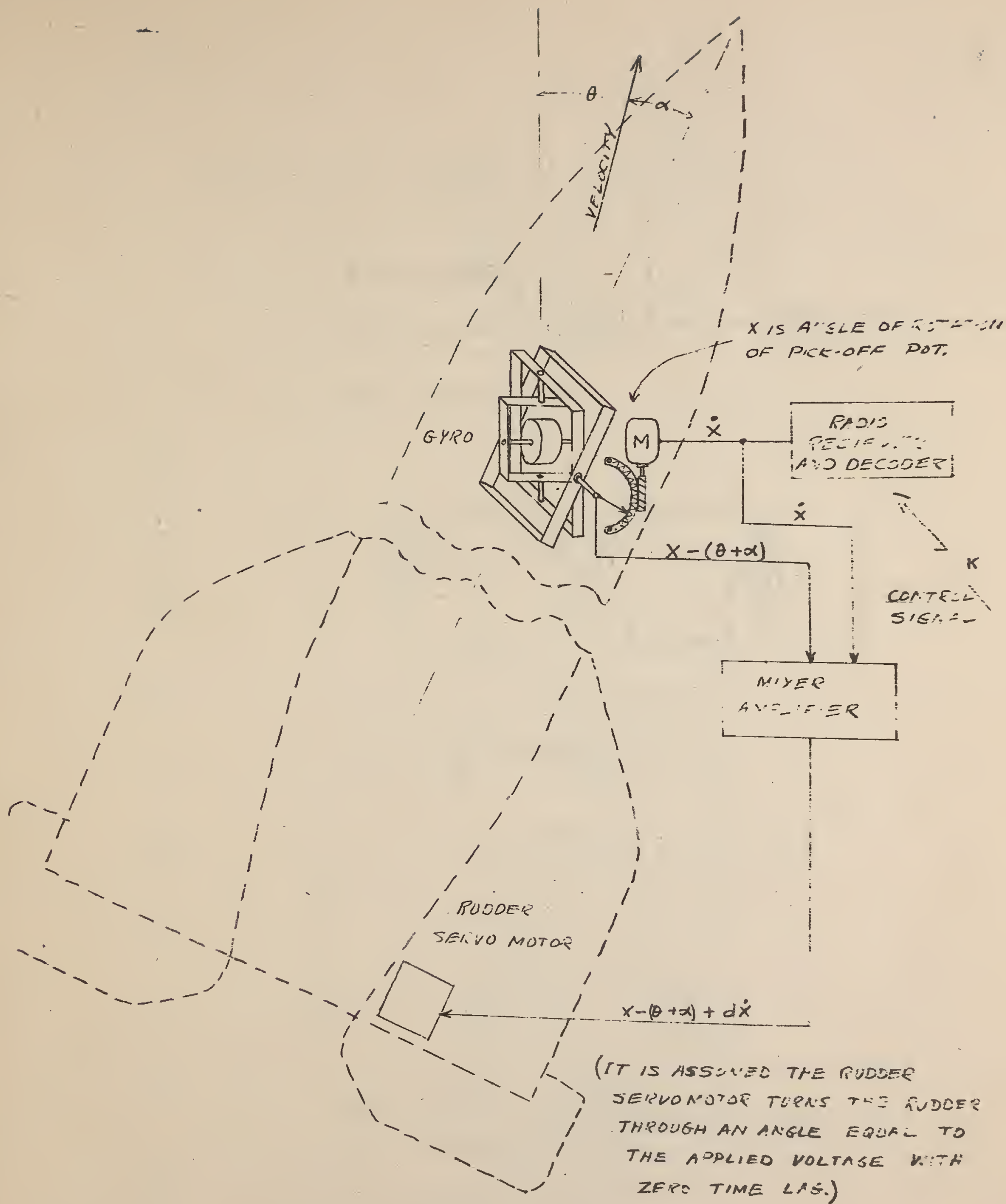


FIG. 6b. SIMPLIFIED CONTROL SYSTEM ASSUMED FOR INITIAL TESTS OF DR. DAVID'S MODEL

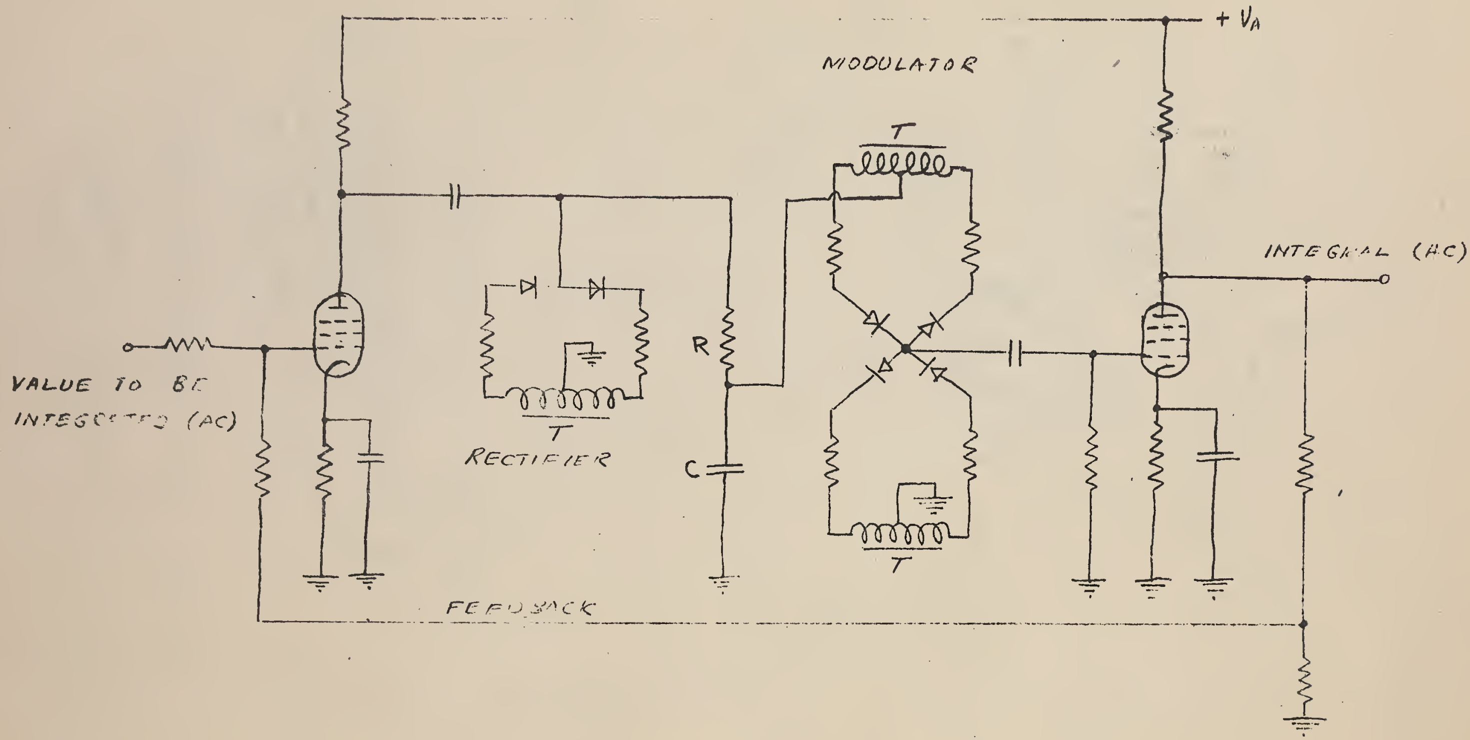
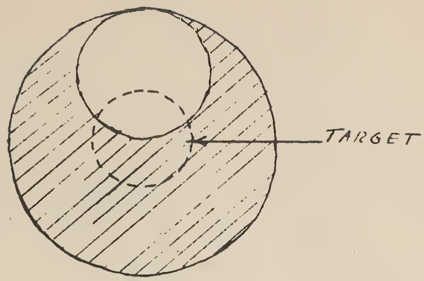
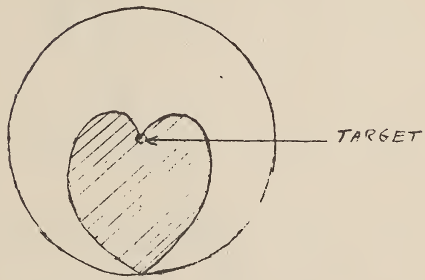


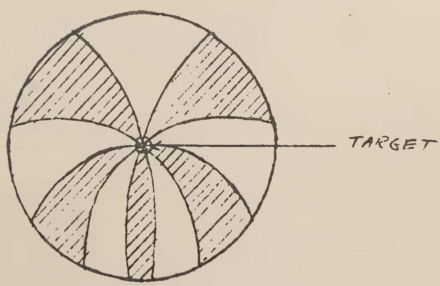
FIG. 7 ELECTRICAL INTEGRATOR (SCHEMATIC)



a. AMPLITUDE MODULATION



b. DUTY-CYCLE MODULATION



c. FREQUENCY MODULATION

FIG. 8 INFRA RED OR OPTICAL SHUTTER DISCS

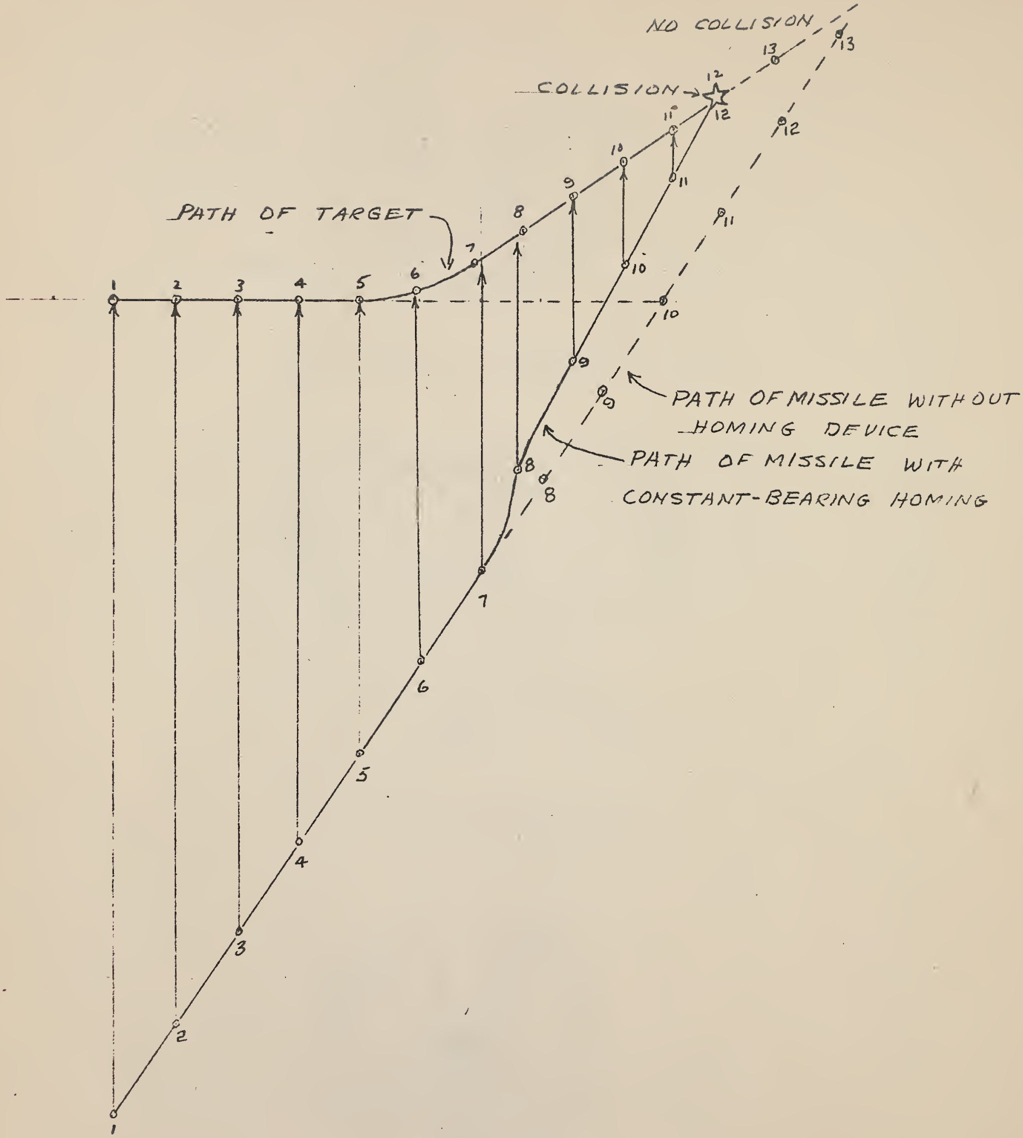


FIG. 9 ILLUSTRATION OF CONSTANT-BEARING HOMING PROCEDURE

CONTENTS Page

Appendices

Drawings

ELECTRO-MECHANISHE WERKE (PEENEMÜNDE)

The Electro-Mechanishe Werke was a very large organisation divided into five departments. Each employee had a number on a decimal system, the directors carrying single numbers, departmental heads two, section heads three, etc. The organisation was arranged as follows:-

EW.1.	Directors.
EW.2.	Development
EW.2.1.	Design
EW.2.2.	Electrical
EW.2.3.	Ground Installation.
EW.2.4.	Progress.
EW.3.	Supply.
EW.4.	Test.
EW.5.	Purchase.

In addition to the Peenemunde establishment various subsidiary works were maintained elsewhere such as at Anklam, Kummersdorf, Bleicherode, Lake Constance. As a result of the Russian advance, it was decided at the end of February to move most of the establishment to Bleicherode in the Harz Mountains. At the end of April with the collapse of the Western Front they were ordered to Ober Ammergau, but stated they feared extermination by the S.S. so they scattered to 12 villages around. They were collected for interrogation at Garmish-Partenkirchen. 5 rail cars full of radio and electrical test gear were found at the station at Peiting. The contents were examined and after an inventory had been made were returned to the trucks.

The Electro-Mechanishe Werke was set up to investigate liquid rockets using A stoff, a cover name for liquid oxygen. Separate reports are attached dealing with the three main weapons produced at Peenemünde, namely the A.4, Wasserfal and Taifun. The history of Peenemünde is given in Prof.v. Braun's "Survey of Development of Liquid Rockets in Germany and Their Future Prospects". (Appendix 1). Appendix 2 gives in chart form the particulars of the full range of "A" weapons from A.1 to A.7 and the future A.9 and A.10. These weapons were developed over the years 1933 to 1945. The work was originally done at the Rocket Experimental Station, Berlin, but Peenemünde was constructed in 1937 to 1938 at a cost of

300,000,000 marks to provide a secluded research station with apparatus to observe the rocket in flight along the Baltic coast. It was stated that the A.4 was the first of these weapons to be tested at Peenemünde. (DR.SCHILLING)

A.T.O. Units

In addition to the weapons A.1 to A.10, Prof.v.Braun mentioned that they had developed in 1937 to 1938 a liquid oxygen assisted take off rocket which gave a thrust of 1 tonne for 45 secs. He could not remember the empty weight of the rocket, but thought that a pair would weight between 500 and 700kg. He stated that they weighed the same as Dr.Walter's H_2O_2 rockets but developed twice the thrust.

Expulsion was by nitrogen, ignition by firework and the oxygen vent valve was electrically operated. The combustion chamber was cooled by alcohol and they were dropped by parachute. These A.T.O. rockets did not get accepted by the G.A.F. because, due to evaporation, it was not possible for a number of aircraft to take off at the same time. About half an hour after they had been filled, a bell rang to indicate to the pilot that the appliance required topping up. If a flight of aircraft was about to take off, the bell might ring and delay the take off of some of the aircraft. Prof.v.Braun stated that he thought the empty weight of A.T.O. units was unimportant because of the greatly increased thrust given to the aircraft. He said that Dr.Walter's three fluid rocket was still in the experimental stage.

Test Stands.

There were 11 test stations at Peenemünde East, reading from North to South as follows:-

Test Stand No.7.

This was the test station in the large oval. The walls contained instrument "bunkers". The wall of the oval was not designed because of blast, but was meant to shield the test station from the sea wind which brought in sand.

There was a large rigid scaffolding in which the A.4 was strapped vertically, the whole was suspended from a large weighing machine so that from 1942 a complete rocket could be given a hot static firing test. The rocket was suspended about 7m above the ground and the gases were directed into a concrete pit shaped like a W. This pit deflected the gases upwards and was lined with molybdenum steel water pipes through which 500 litres of water per sec was circulated. The rockets were brought out of the large shed in which they were stored and adjusted. They were carried by a conveyor crane which lowered them into the scaffolding. The crane was kept there to protect the test workers from the weather and was then moved before firing. (ENG. TESSMANN) In spite of some evidence to the contrary a statement was made that actual flight firings were also carried out within the oval.

Test Stand No.1.

This was also designed to enable the test to be made of a complete rocket, but it was not regarded as satisfactory as No.7.

Test Stand No.8.

For static tests on thrust motors only.

Test Stand No.9.

For testing the Wasserfal.

Test Stand No.2.

This small stand was used for testing $1\frac{1}{2}$ tonne rockets presumably A.3 and A.5. Later was used for testing valves and components.

Test Stand No.4 and 3.

Used for A.T.O. Units.

Test Stand No.5.

For testing Turbo-Pump units for A.4.

Test Stand No.6.

Wasserfal.

Test Stand 10 and 11.

Situated one on the sea shore and the other in the circle inland, were used for flight firings of A.4s and Wasserfal.

The A.4s arrived by railway and went into the big house where they were picked up by two cranes, the larger 32m high picked up the nose of the rocket by means of screw bolts screwed into the head. The small crane picked up the rocket in the middle and the rocket was transferred to vertical position. It was taken to Test Stand No.7 in a Brennstand wagon. (ENG.HEUER)

LIQUID OXYGEN

Liquid oxygen was made at Peenemünde. They had two compressors (each two cylinders). The storage tanks were spherical. They had two each 50,000kg capacity suspended from an iron scaffolding and insulated with magnesium powder. The liquid oxygen was made at the rate of 500 to 600 kg per hour. Peenemünde also received supplies of liquid oxygen by rail wagon holding 22,000kg. From the rail wagon or the storage installation the liquid oxygen was taken to the test stand in road wagons of which the smallest held 5,000kg and the largest 8,000kg. The road wagons were insulated with 30cm of magnesium powder. (DRIVER MANTEUFFEL) Eng. Bärwald who was in charge of the liquid oxygen chambers for the A.4 said that the road wagon could hold 6,700 litres and were insulated with 5cm of glass wool (Hyporka) with a sheet metal outer covering. The loss from this wagon was 350 litres per 24 hour day. The liquid oxygen was pumped from the road cars to the A.4s by means of a portable petrol engine driven pump which could be carried by two men and mounted on the road cars.

The liquid oxygen was transferred from a road car to the inside of the A.4 by means of a long rigid pipe 7cm inside diameter covered with woven insulation.

Co-ordination of Peenemünde Technical Data.

Some 400 persons were maintained at Divisional Headquarters, Garmish-Partenkirchen for interrogation. Among these were many important men such as:

Gen. von Dornberger, in charge of all Rocket Development in Germany.
Prof. von Braun, Technical Director.
Dr.Steinhoff, Head of the Electrical Section.
Dr.Schilling, Static and Firing Tests.
Dr. Dannenberg, Head of the Design Section.
Dr.Fricke, Chief Designer for Solid Rockets of Rheine Metal-Borsig.

Unfortunately Dr.Tchinkel, the Chief Chemist was missing. All files and drawings were alleged to have been taken by S.S. Gen. Dr.Kammler, who may possibly have walled them up in a mine shaft at Bleicherode. Only 450 people were ordered to evacuate to Ober Ammergau out of the 4,000 who left Peenemunde for Bleicherode. Of the 400 in Garmish-Partenkirchen, Gen. von Dornberger and Prof.von Braun prepared a list of some 200 persons whom they said were of minor importance and could be sent to their homes. Everyone of these persons was interviewed and a proportion were earmarked for further detention. The rest were given transport towards their home districts.

With regard to the 200 qualified engineers and scientists who remained at Divisional Headquarters, Garmish-Partenkirchen, it is obvious that in the course of two to three weeks work, it was quite impossible to extract the full story of the rocket weapons or to go deeply into any one of the scientific facets of this work. From the psychological point of view, although up to now most of the staff have been willing to talk, whether or no this will continue, will depend upon whether one can foster the confidence that the team will not be dispersed and may have the opportunity of continuing their work even if only on a very much reduced scale. The attitude of co-operation maintained up to now has been mainly due to the lead set by Gen. von Dornberger and Prof. von Braun, who take up the attitude that if they can convince the British and Americans of the value of their work, there is a chance that facilities may be offered in England or America for continuing it. Disposal of the Section Leaders or removal of the management will destroy this attitude and the team as a whole may no longer be technically helpful. Should authorities wish to obtain the high altitude data as proposed by Prof. von Braun or to launch A.4s and A.9s, much time could be saved and risk to material and life avoided by utilizing the unique experience of this team of workers.

A.4. In the course of interrogating some 40 persons, the following details were obtained in respect to the construction, test and operation of Rocket A.4.

A. War Head.

Sometimes when rockets were launched they failed to fly along the controlled path, or due to a fault in the electrical connections the Power Cut-off (Brennschluss) took place too early. Then the rocket would fall back to a place on or near the launching site. If the firing "programme" had not been completed the War Head did not explode on reaching the earth because the fuze was not armed until the end of the "programme". On the other hand such an accident usually resulted in an oxygen-alcohol fire and due to the heat generated the War Head was likely to explode at the end of half an hour. (PROF. v. BRAUN)

Skin Temperature.

Measurements have been made to ascertain the skin temperature reached during the rocket's downwards flight through the atmosphere at supersonic speeds. These were obtained:

(a) By means of models made of rubber-like materials in the surface of which thermocouples were inserted. The models were tested in the Peenemünde wind tunnels which were later removed to Kochel. The temperature of the skin was found not to exceed 600° C. (DR. HERMANN and DR. KURTSWEG)

(b) The skin temperatures were measured in flight by a method described by Dip. Eng. Schuler. Small discs of various metals of known melting point were inserted into the skin of the rocket and connected to electrical circuits. As each patch melted a signal was transmitted by telemetering to the observation station. The skin temperature nowhere exceeded 650° C. Prof. v. Braun demonstrated that although the film stagnation temperature might be as high as 1100° C, due to soakage and radiation, the skin temperature was not likely to exceed more than half this figure. He pointed out that if meteorological examination was made of fragments after an air burst, it would give a misleading result because such fragments would be heated to higher temperature than

than the normal skin temperature as they would be receiving heat on both sides of the skin during their passage as fragments through the atmosphere. Further the force of the explosion would give these fragments an abnormally high velocity.

B. Alcohol Tank.

According to Document B.14 which describes the choice of timing of the Brennschluss, the normal fuel content would be 3,797 Kg. of 75% ethyl alcohol and 25% water. During flight this tank was pressurized to 1.4 atmospheres. For 40 secs. this was achieved by ram compression through the pipe leading to the War Head. At the end of 40 secs the rocket reached a height where ram compression was no longer effective, so that the valve was shut by the "programme" control and thereafter by the nitrogen bottles in the radio compartment. The fuel tank was kept pressurized throughout the whole of the flight. (DR. ZOIKE)

No definite answers were obtained to queries regarding the cause of air bursts and it would appear that they were either uncertain regarding the cause, or unwilling to divulge it. Several persons (among them Prof. v. Braun and Eng. Finzel) mentioned the difficulty of preserving the fuel tank during its downward path through the atmosphere. Apparently it was likely to be destroyed due to:

(a) Excess differential pressure between the external atmosphere and the pressure within the tank.

(b) Differential pressures on the fore and aft ends of the tank due to aerodynamic distribution of pressure on the outside skin of the rocket. As the skin was by no means air tight the pressure distribution within the rocket corresponded to that on the outside skin with a corresponding tendency for the tanks to have a large resultant force exerted on them towards the tail of the rocket. This tended to tear the tanks away from their connections to the chassis with consequent tank collapse which might cause an explosive mixture of alcohol and oxygen to be brought into contact with the external skin at a temperature of 500° C to 600° C.

In order to overcome these difficulties a new method of supporting the tank was developed. This involved holding the tank in broad sheet steel strips which were in turn attached to the chassis. Such a tank was found Blizna. About a hundred of this type were made and they avoided welding the suspension connections to the skin of the tank. They were rejected for operational use as it was too heavy. The capacity of the fuel tank was 4,460 litres. Some larger tanks were made for A.4 towards the end of the war, but were never used (ENG. FINZEL)

C. Oxygen Tank.

The capacity according to document B.14 up to the overflow point was 4,960 Kg. The same document describes the loss by evaporation while standing preparatory to being fired as 2 Kg. of liquid oxygen per minute. The range tables were drawn up on the assumption that a 30 minute wait before firing involved a loss of 60 Kg.

Prof. v. Braun said that sometimes during the filling operations they would be interrupted by enemy air raids. This caused a waste of liquid oxygen and under pressure from those responsible for the operational handling of the rocket, lagged oxygen tanks were tried. Prof. v. Braun said that the lagging was not successful as its heat capacity was such that it transmitted a large quantity of heat to the oxygen and this during the filling operation actually increased the loss of oxygen. The filling operation only took 12 minutes.

Although the Stoichometric ratio of oxygen to alcohol-water was 1:0.64, they used operationally a ratio of 1:0.85 so that the equivalent of 3,797 Kg. of alcohol would be 4,480 Kg. of liquid oxygen. (PROF. V.BRAUN)

There would be some 400 Kg. of surplus oxygen and a quantity in excess of this might have been left in the oxygen tank after Brennschluss.

The vent valve was of an ingenious design and the object of the double seats was to enable the valve to open and shut at lower pressures. The valve served a double purpose. It could be held shut by high pressure nitrogen. It was so held shut to the moment of filling began and also during the firing period. The valve also acted as an automatic relief valve, opening and shutting to maintain a pressure of 1.2 atmospheres (gauge). During the operational period the heat exchanger was designed to maintain a pressure of 1.5 atmospheres (gauge) at the suction side of the oxygen pump. (DIP. ENG. ZOIKE)

In order to prevent collapse the oxygen tank was maintained with an internal pressure throughout the whole period of flight. They realised the danger involved if the vent valve failed to re-open at the end of the operational period, it being felt that the chance of it being iced up was remote. It was connected by a long pipe to the outer skin of the rocket. The valve was shut until filling began. Due to this the gases only passed in one direction, that is, from valve to atmosphere and hence there was no opportunity for moisture to get to the valve with consequent ice formation. It was agreed that the dangers associated with ice were far greater on wet days. The small Buna Piston used in the vent valve was adopted in spite of the advice of experts, but proved very satisfactory in operation. (PROF. v. BRAUN)

D. Heat Exchanger.
(Liquid Oxygen-Steam)

This was designed by Eng. Bedürfrig who was not amongst the staff kept for interrogation at Garmisch.

E. Main Oxygen Valve.

The main oxygen and alcohol valves when not pressurised by high pressure nitrogen were both open about 8 m.m. The oxygen valve with which we are familiar, having a small central valve, was an experimental type, the small valve being eliminated in later production models. The rheostat was used to check the operation of the valve on the test stand by means of a Wheatstone Bridge and Oscillograph, but the troops in the field used the electric contact to check that the valve opened and shut correctly. (PROF. V. BRAUN).

They had a great deal of difficulty with the packing rings through which the operating piston of this valve slid. They tried Buna but it was not satisfactory because, although it did not break up at liquid oxygen temperature, it lost its resilience. Eventually they found a synthetic substance IGAMIT made by Venditor Kinstoff Fabrik of Fruisdorf, Nr. Cologne. They used this substance as the resilient outer sheath of the rings and had a centre hard core of tape wound construction vulcanized. The first samples of IGAMIT were extruded and proved to be very resilient at low temperatures. Later on when the rings were delivered, having been manufactured by pressure moudling, they were no good. (ENG. PASTWA)

F. Turbo-Pumps.

Eng. Hübner who formerly worked with Prof. Walter Keil went to Peenemünde and supervised the test of the Turbo-Pump units on Test Stand No.5. He gave the following data regarding this unit. The ratio of T stoff to Z stoff was 14:1. (Storage capacity 130 litres T stoff, 10 litres Z stoff). When the electrical contact was made to start the Turbo-Pump unit, both T stoff valves (main piston and solenoid by-pass) opened together and the unit came up to full speed in 3.5 secs. (Dip. Eng. Zeike in his description of the starting cycle said $2\frac{1}{2}$ secs to full speed. Prof. v. Braun said 1/5 sec.) On the test stand the unit ran at 4,000 R.P.M. developing 540 H.P. During operation, the revs were from 3,600 to 3,800 R.P.M. At 4,000 R.P.M. the consumption of T stoff and Z stoff is 2.5 Kg/secs. Should anything go wrong with the turbine, lest it should go too fast, it is provided with a "snellschlusse" which cuts off the T stoff at an over-speed.

The steam temperature as fed to the turbine was 400-420°C. It was essential that this should be kept constant. The T stoff as provided in the field would vary in its concentration and so adjustments had to be made by adding more or less water to the Z stoff. (PROF. V. BRAUN) This accounted for the rather unusual ratio of T stoff to Z stoff since for G.A.T.O.R. and H.S.293 the ratio was approximately 25:1.

The steam pipe was insulated for a dual purpose. To (i) keep the steam warm and (ii) to prevent fires which might occur should there be an alcohol leak in which case the alcohol might get splashed on to the bare steam pipe and ignite. The Z stoff was poured in from a can at the last moment before firing. It was warmed to about 30°C and might drop on standing to 5°C. The tank was described as being capable of standing for two hours at -20°C. If after a certain time the rocket was not fired, a door was opened in the side of the turbine chamber and a lance inserted which blew hot air over the Z stoff tank (the air was heated externally by electric means.)

Prof. v. Braun said the the Turbo-Pump chamber did not get very cold due to a thin aluminium diaphragm which stretched right across the rocket underneath the liquid oxygen tank.

The range was controlled by the timing of the Brennschluss. They must have met severe difficulties due to "water hammer" which caused them to shut down in two stages. Stage 1 at the Vorkommando reduced the thrust from 25 tonnes to 10 tonnes in about 2 to 2½ secs. This was achieved by shutting off the main piston operating the T stoff valve, thereby reducing the flow of T stoff to ⅓ of its normal volume the revs now being 2,000 R.P.M. Later the solenoid T stoff valve was also shut and the thrust drops to nil in about 2 secs. There is a variation of this procedure which makes the pre-shut off stage 8 tonnes thrust.

Care is taken that no T stoff should enter the re-action chamber until there is an assured supply of Z stoff. The Z stoff on entry operates a diaphragm contact which in turn makes the necessary electric contacts to cause both T stoff valves to open. This diaphragm contact is known as the Rubidkontact.

G. <u>Reducing Valve for Turbo-Pump Unit and Servo Valves.</u>

The reducing valve was designed in Peenemünde. It had to control the low pressure at 33 atmosphere (gauge) with a reliable variation of 0.6 atmospheres. The valve was supposed to function while the high pressure bottles dropped from 200 atmospheres to 50 atmospheres (gauge). The valve contains two flexible diaphragms and its adjustment is sensitive to variations in temperature. When cold the valve does not function so accurately. In order to counteract this, the valve was electrically heated. (ENG. HOYER).

Eng. Böttcher was employed on testing reducing valves. The valve was tested by blowing nitrogen through from some high pressure bottles and allowing the high pressure to reduce slowly while the controlled pressure on the low pressure side was measured. He did not know the magnitude of the gas flow. The measurement was made by means of a Bourdon Tube, plus a Potentiometer, plus Oscillograph. The manufacture of these valves was carried out by three or four external firms. Another reason suggested for electrically heating the valves was to counteract the cooling of the nitrogen as it expands in the reducing valve. From 1944 onwards a great deal of the work on the rocket fittings was carried out at Anklam, about 40 to 50 Km. away from Peenemünde.

The normal delivery pressure of both pumps was 25 atmospheres (gauge). (ENG. HOFFMANN)

During the function of the power plant due to the quantity of liquid oxygen in passage from tanks to combustion chamber, the ambient temperature around the Turbo-Pump unit and combustion chamber fell to -10°C.

H. Combustion Chamber and Burners.

Prof. v. Braun said that the design of burner cups was his essential patent and formed the basis of all the "A" weapons. Just as T stoff was used as a cover name for Hydrogen-Peroxide, so A stoff was used for liquid Oxygen. There is a fair amount of evidence to indicate that most of the fundamental research associated with the "A" weapons was not done by Prof. v. Braun and his staff, but was carried out by various Professors at the Dresden Institute of Technology and at other similar institutions. The early work at Peenemünde before the war was concentrated on 1 tonne thrust chambers (probably for A.T.O. units). These chambers operated with only one burner cup with the type of which 18 are employed for A.4. The next stage was combustion chambers with 3 burner cups for 4 tonne thrusts. From this stage they went straight to the 18 cup assembly for A.4. It was preferable for the liquid oxygen and the alcohol to arrive simultaneously, but if one had to come first it must be the oxygen. In practice they found that it took about 1 sec to establish the flow of liquid oxygen. (ENG. LINDENBERG)

It is reported that in 1939 to 1940 Prof. Beck at the Institute of Technology, Dresden, carried out fundamental research on the combustion of alcohol and liquid oxygen. Small combustion chambers were built for experimental purposes. One of these had a thrust of 1 tonne. Experimental chambers were run for one minute. They were established in an experimental station at Kummersdorf. In 1940 Prof. Beck was transferred to the Institute of Automobile Engineering, Berlin, where he died the following year.

It was reported that the combustion system of the A.4. was invented by Dr. Thiel. He was killed in the first large raid.

Eng. Hans Lindenberg said that from 1930 onwards he was doing research at the Technical School, Dresden on fuel injectors for deisel engines. He stated that the design of the fuel injection nozzles for A.4 was settled at Dresden. They had a laboratory for measuring the output and for photographing the spray of the alcohol jets. Eng. Lindenberg said that:

(a) The output of the alcohol jets was constant for a given pressure drop across the jet, i.e., was not affected by the back pressure due to the pressure in the combustion chamber.

(b) The alcohol jets gave the same calibration during "hot" operation of the combustion chamber as was obtained during "cold calibration.

In the burner cups plain cylindrical alcohol jets were used at the cool end near the oxygen sprayer. Wide angled alcohol sprayers were developed for use at the hot end to keep the surface cool.

Eng. Lindenberg, from 1940 onwards, worked part of the time in Dresden and part at Peenemünde on the development of the combustion chamber. The normal atomizing pressure was 3 atmospheres.

Prof. v. Braun said that the flame front was established just inside or at the mouth of the combustion cups. He agreed that this condition was associated with a possibility that the combustion chamber head might get burnt, but pointed out that if the flame front is allowed to form at a distance away from the burners, the efficiency of combustion and specific impulse would suffer.

In respect to the cooling jacket, the frictional drop was reported as 5 atmospheres and the temperature rise would be from 10°C to 40°C, i.e. 30° C. (ENG. HOFFMANN)

Eng. Lindenberg said that the temperature rise was between 40° C and 60° C. He explained the functioning of the 36 screw plugs which are set in the wall of the combustion chamber in groups of 3 upstream of the ventury throat. Each plug is drilled with 4 small holes. What was not apparent from examination of a used rocket, was that before firing these 144 holes were filled with Woods or other low temperature melting metal. When the skin of the combustion chamber reaches a certain temperature the metal plugs melted and additional surface cooling is provided for the throat of the venturi. The metal strips in the cooling jacket serve a dual purpose of preserving the width of the cooling space and also carrying out the more important function of strengthening the combustion chamber at a point where it is most likely to suffer from any excessive pressure due to an impulsive start. There is one unexplained small connection to the large annulus at the feed-in and of the cooling jacket. From this a small pipe was led to the outside of the rocket and this provided the only means of draining off the alcohol in the event of something going wrong during a combustion test on the test stand. (ENG. LINDENBERG)

Dr. Haller mentioned that for combustion chambers up to 1 tonne thrust spray cooling is necessary.

The mass flow of fuel was as follows as given by Dr. Palm:

During the first 5 secs operation (under gravity feed) 7 Kg/sec. (Eng. Hoffmann stated that there was approximately 8 kg. of each fluid per sec for the first 5 to 7 secs). When the pumps had reached full speed the mass flow of both fluids was 127 kg/sec which gave a thrust of 25 tonnes. (Dr. Zoike said that the mean thrust was 27 tonnes, the thrust rising by 4.2 tonnes in the course of flight.) (Eng. Hoffmann stated 135 Kg/sec which equals 60 kg/sec alcohol plus 75 Kg/sec oxygen.)

Various figures were put forward regarding the specific impulse obtained. Prof. v. Braun said that for operational purposes they reckoned on an impulse of 4.75.gm/kg/sec (210lb/lb/sec) but on the test bed they had achieved an impulse of 4.5gm/kg/sec (220lb/lb/sec). . The reported thrust of 25 tonnes with a mass flow of 127kg/sec is equivalent to a specific impulse of 5.08gm/kg/sec (197lb/lb/sec). Dr.Haller said that for relatively small combustion chambers they could use 95% alcohol as a fuel, but this gave too hot combustion chamber conditions for large chambers. The small chambers do not require surface cooling. Some six or seven years ago they tried using gasoline as a fuel. Prof. v. Braun said that it was unsatisfactory. Combustion conditions were not as good as with alcohol and persons working on the test stand were covered with soot. The main objection to the use of aviation spirit was that it did not function well as a coolant, tending to give unequal cooling to the different parts of the surface and also to form gas locks.

The venturi could not be designed to give the correct expansion, both at ground level and at the end of the firing period. During this period the thrust rose from 25 tonnes to 29 tonnes due to the decrease in the external pressure. As a compromise the venturi was designed for an expansion down to 0.85 atmospheres (absolute).

I. Gas Rudders

Dr. v. Braun said that the graphite used for these rudders was the same as that used for electrodes in electric furnaces. He pointed out that the function of the gas rudders was to stabilize the projectile during the first part of its flight until it attained a sufficient speed for the tail fins to ensure stability. They had experimented and found that they could substitute oak gas rudders instead of graphite, because the oak would last for the necessary few seconds.

J. Testing the A.4.

All the fuel nozzles were independently calibrated and later were again calibrated in situ by means of a static cold blow-out test carried out on a combustion chamber unit from fixed weighed tanks. In this test the liquid oxygen was directed into flexible hoses back to a sump, while the alcohol was caught in a large funnel about 3 feet in diameter and led back to another tank.

Up to 1942 it was not possible to give the complete rocket a hot static test. The combustion chambers, however, were given a separate hot static test and the thrust was measured by large balanced arms weighing machines made by Sülz of Toledo, Nr.Cologne. The weighing machines had a needle on a dial as an indicator and this was photographed by high speed camera throughout the run.

They had tried to measure the thrust on a whole rocket before 1942, but the scales were not sufficiently accurate. From 1942 onwards, arrangements were made so that on Test Stand No.7 the complete rocket could be suspended in a scaffolding which was hung from a weighing machine, so that the thrust during a hot static run could be measured. (ENG. TESSMANN)

The Establishment built up an elaborate range of instruments so that they could record the behaviour of the rocket during static tests. In order to ascertain the rate of flow of the working substances, special flowmeters and test gauges had to be developed for liquid oxygen and alcohol tanks and pipe. These instruments are described in a separate report recording information given during an interrogation of Dip. Eng. Schuler, whose sole concern was measuring and metering problems on the A.4 and other weapons.

In addition to making elaborate measurements on the thrust motor and the whole rocket during static tests, arrangements were made to measure and transmit to the ground station the more important data during flight. Dr.Schuler reported that he left Peenemünde with the second group evacuation and that he thought that most of the special instruments would be sent to Lehesten, near Salfeld, Leipzig where it was intended to continue work on combustion chambers.

All the instruments in the rocket were designed so as to oper. to indicators and recorders a considerable distance away. The instruments and observers were housed in underground observation chambers known as "bunkers". When testing thrust motors alone, the nearest bunker was 15 metres away. When testing whole rockets the procedure was regarded as being very much more dangerous and the instruments were housed in a bunker 100 to 150 metres away

K. Firing the Rocket.

The range tables gave the brennschluss time and velocity for a given all up weight and desired range. Originally the Brennschluss was operated by radio command from a ground station. Later this was done by the Gyro-accelerometer and then by the Buchold Electrolytic Integrator. A fourth more accurate system was in process of being developed whereby the acceleration time curve would be kept constant by controlling the flow of T stoff to the Turbo-Pump unit.

The bearing was controlled by the rotating launching platform which was set in the same manner as when firing a gun. For this purpose a direction telescope and a Leitz Colimeter were used. The training of the projectile on the right bearing was done from the ground, so that it was first necessary to measure by optical methods the angle between the reference plate near the ground and the mounting of the gyro in the control compartment. (DR. ROSENTHAL)

Before filling the rockets the tanks and valves were tested for tightness by pressurizing the valves to 1.8 atmospheres and seeing if this was maintained for 5 minutes. The T stoff and Z stoff valves and tanks were also tested.

The liquids were put in in the following order:

1. Fuel
2. T stoff
3. Liquid Oxygen

} These were all pumped direct from truck to projectile.

4. Z stoff. Poured out of a can.

L. Ignition.

When the rocket was ready to be fired an igniting torch was lit. There are two types:

(a) A Pyrotechnic (black powder) ignitor, and

(b) A liquid operated torch using a "Hypergol" pair of fluids such as nitric acid and Visol.

They preferred the firework because the liquid ignitor required more attention and had to be refilled between each use. When the firework was alight the nitrogen was cut off from the main alcohol and oxygen valves, which caused them to open to their natural positions, namely about 8 m.m. open. The alcohol and oxygen now flows through the pumps under a gravity head from the alcohol tank and a pressure of approximately 1 atmosphere in the oxygen tank as the vent valve is held shut during the operational period. The flow of alcohol and oxygen which amounts to 7Kg/sec-15Kg/sec, according to different authorities, lights quite easily. If all 18 burner cups light simultaneously there is no shock, but if some ignite immediately and the rest later there is a moderate bang when this occurs.

These conditions are maintained for 5 or 6 secs until the operator is assured that ignition is satisfactorily attained and an adequate temperature exists in the combustion chamber. When only thrust motors are being tested the observer, being about 50 feet away, can judge by the glow in the exit from the venturi. If a whole rocket is being tested, the observer is much further away and they have used heat sensitive devices such as thermocouples to indicate electrically that ignition has been achieved. When this is so, the operator makes an electric contact which sets the T - Z stoff system in operation. The Turbo-Pump rapidly reaches full speed and while this is happening the thrust exceeds the weight of the full projectile, so that if it is not being statically tested it leaves the ground.

WASSERFALL. (C.2).

This guided anti-aircraft weapon had been in the course of development since 1940. At the end of the war it had not been used operationally, being still in the development stage. Evidence obtained at the Wind Tunnels at Kochel shows that at least six different shapes had been tried out to get the best aerodynamic results. The shape adopted for operational use is shown on Drawing No. on which all the dimensions are given in terms of the diameter. An approximate specification is given below.

Diameter - 88cms.
Overall length - 7.87 metres.
Span - 1.9 metres.
Empty weight - 1760Kg.
Weight of acid - 1600Kg. Weight of fuel 385kg.
Weight of high pressure nitrogen - 70Kg.
Thrust - 8 tonnes.
Duration of burning time - Slightly less than 45 secs.
Mass fuel flow - Approximately 45Kg/sec.
Specific Impulse - About 178lb/lb/sec.
High pressure N_2 260 atm. (gauge). Reducing valve 25-27atm(gauge)

Most of the information regarding the Wasserfal came from Drs. Heller, Palm and Zeike. The fuels to be used were mixed acid (90% nitric acid and 10% sulphuric acid) with Visol or Optolene. It is probable that the Visol (C_2H_5-O.CH=CH_2) would be mixed with Aniline to promote combustion, although mixed acid was described as being more readily self-igniting with pure Visol than straight nitric. The Optolene consisted of 5 components and was roughly made up of, 50% Visol, 10:20% Aniline, the rest being Optol (a coal tar raw product containing Phenol which inhibits the formation of C_4H_4), Benzol and Xylol (this also prevents the formation of C_4H_4 crystals.) The mixture is reputed to have a specific gravity of approximately 0.9. The Stoichemetric mixture was one part of acid:0.22 parts of fuel, but for operational purposes they used one part of acid:0.24 parts of fuel. The theoretical specific impulse for mixed acid and Optolene was 214lb/lb/sec, but they actually obtained about 183. Dip. Eng. Schilling who was over all experimental work at Peenemünde said that for practical purposes they accepted impulses 15% lower than the theoretical.

Other figures quoted for these fuels were:

One part nitric acid plus 0.23 parts Visol. 214lb/lb/sec.
0.9 parts nitric acid plus 0.1 part sulphuric acid plus Visol, 204lb/lb/sec.
0.9 parts nitric acid plus 0.1 part sulphuric acid plus Optolene, 204lb/lb/sec.

At a later interview Dr. Heller said that taking an average specific impulse of say 4.9gm/Kg/sec, changing the fuel from Optolene to Wisol etc only made a difference of + or - 1/10gm in the specific impulse.

It was hoped to store these weapons fully loaded with liquids for a minimum period of 6 months and preferably for a year before firing. As both liquid vessels were fitted at each end with aluminimum bursting diaphragms, it was essential that in storage the pressure within each tank should not exceed a pressure likely to burst the diaphragms which were designed to go at 10 atmospheres differential pressure. For experimental purposes a ullage space of 33 litres was left in the acid tank; for operational use 48 litres was left. In the fuel tank for experimental purposes they used a ullage space of 13 litres, but in the operational model this was between 18 and 20. The storage life was tested by filling at 10°C and then raising the ambient temperature to 40 or 50°C.

Below is given a description of the internal arrangements of the Wasserfal from fore to aft.

1. Radio and Fuze Compartment.

A great deal of work had been done on the radio steering device, proximity fuzes and Homing devices for this weapon. No definite decision had been made regarding the types to be used for operational purposes.

2. War Head.

Believed to be about 300Kg.

3. High Pressure Gas Bottles.

Diameter - 70cm.
Storage capacity - 235 litres (70Kg) nitrogen at 260 atmospheres (gauge).

They had experimented with compressed air instead of nitrogen, but the results were not available. The nitrogen bottle is equipped with hand operated valve, pressure gauge and filling connection. After this is an explosive operated starting valve presumably similar in design to that used on H.S.293.

4. Reducing Valve.

The reducing valve for this weapon had been specially designed because the gas used for the expulsion of fluids at such a high rate was a very large quantity, i.e. 33 litres/sec at the controlled pressure of 25 atmospheres (gauge). The low pressure controlling compartment was in a bellows and the loading was by a long powerful spring with an adjusting screw. The whole valve might weight as much as 10Kg and also from 50cm long.

After dispersal from Peenemünde in 1944, work on the internal fittings of the Wasserfal went on at Anklam. The valve was manufactured for Peenemünde by Messrs. Hübner, Maier of Vienna. Under test the valve did not give fully satisfactory results, as the controlled pressure apparently fell off when the high pressure side got as low as 90 atmospheres. They had apparently spent a lot of time trying to make the valve work well both at the start when it was subjected to heavy shock on the firing of the initiating valve, and at the end of operation when the gas bottle was nearly exhausted. (ENG. HIRN, ENG. TONNESSEN)

5. Three-way Valve.

According to Eng. Tonnessen, the gas after passing the reducing valve went to the three-way valve. This valve had four connections, one leading to atmosphere, one to the reducing valve, one which branched to the fuel tanks and one to a safety valve which opened in the event of the control pressure exceeding a certain limit during operation. The three-way valve was described as being operated by cartridge before the firing valve was fired. It carried two poppet valves and during storage the one leading to atmosphere was opened and the one leading to the fuel tanks was shut. On firing the first cartridge, this condition was reversed. If before launching the projectile one had fired the cartridge to close the vent valve and then decided for operational reasons not to fire the projectile, a second cartridge could be fired which would reset this three-way valve to its storage condition.

6. Tanks.

The gas line branched to the two liquid tanks which formed part of the skin of the projectile. The upper tank contained the fuel, while the lower tank contained the acid. They had apparently tried many methods of making the acid tank in order that the projectile could be capable of being stored for a long period. The following methods of construction were mentioned.

Dr. Palm. Steel with aluminimum inner skin.
Eng. Tutz and Hellebrand. Manganese steel.
Eng. Tonnessen. Enamelled steel.
Eng. Bringer. 4% Chrome steel (Luftwaffe Specification No. 1604).

Before entering the tanks the compressed nitrogen had to burst two diaphragms made of aluminimum in which circular V grooves had been cut. The groove did not form a complete circle, the diaphragm being left uncut for a sector of about 30° in order to form a hinge when the gas pressure burst open the diaphragm and bent back the disc.

The forward acceleration of the projectile with a thrust of 8 tonnes must have been approximately 2.1g at the start and 4.5g at the end. It was designed for a lateral acceleration of 12g. With such lateral acceleration the meniscus of the fluids was described as standing at an angle of 20° to the axis of the projectile. There must have been alternative designs for the fuel tanks because Dr. Palm said that the swing of the fluid was dealt with by suspending a delivery pipe from the roof of each tank. The delivery pipe was articulated by means of a metal bellows. On the other hand Eng. Binger drew a sketch of the tanks which showed a central passage way through each tank. This passage way was used for the fluids and gas lines and the lateral acceleration was apparently countered by the provision of rotating feed pipes which followed the fluids to the side of the tank.

7. Jets - Combustion Chamber.

After leaving the tanks both fluids passed through aluminimum burster diaphragms and the fuel passed through a choke which compensated for the frictional pressure drop of the acid in its passage through the cooling jacket. (ENG. TONNESSEN) The acid passed through the cooling jacket at a maximum velocity of 4m/sec (width of annulus 5-6mm.) and rose in temperature 60°C with a pressure drop of 1.5 atmospheres. At arrival in the combustion chamber head both fluids were sprayed into the chambers by means of the arrangement shown on Drawing No.   made by Dr. Palm. By this arrangement a quarter of the holes were devoted to jets of fuel and acid spraying against each other for ignition purposes, while the remaining 75% of the holes were arranged in pairs, fuel against fuel, and acid against acid to promote atomization. The pressure drop in the fuel jets was 2 atmospheres and in the acid jets 3 atmospheres. The combustion chamber had a capacity of 75 litres and a venturi throat of 192m.m. The L* was therefore 100". The designed combustion chamber pressure was 20 atmospheres (absolute) with a theoretical temperature of 2800°C. The molecular weight of the gas complex in the combustion chamber was about 26, the possible temperature after expansion 1600°C. They assumed that the gas complex "froze" at 1800°C. The combustion chamber was made of mild steel. There is no surface cooling.

With regard to ignition it was mentioned that no pair of fluids was used in a combustion chamber if it did not ignite in an open cup test within 0.05-0.1 secs. A check test was done in an atmosphere of nitrogen. Shortest ignition time for any pair of fluids was 0.025sec.

8. Wings and Fins.

The general dimensions of these can be obtained from the Wind Tunnels at Kochel, but verbal information was obtained as set out below.

Eng. Dahm gave the span of the wings as 1m.60 and the length of the wings 1m. He stated there were no jet rudders, saying that these cut down the performance. He confirmed that the steering rudders extended beyond the span of the wings.

Eng. Hellebrand drew a sketch of the Wasserfal, in which the wings are dimensioned as span 1.88m., chord at the body 1.7m, chord at the tip .06m. section bi-convex. Steering rudders 80cm x 30cm. Eng. Hellebrand said that gas rudders were used.

9. General.

The Wasserfal was launched vertically. One engineer said that there were no gas rudders, but Dr.Heller confirmed that there were. It was possible that these were made out of oak.

Dr. Schilling and Heller were interrogated regarding the times of arrival of the fluids. One witness said the fuel arrived first because of the shorter path, but another said the acid arrived first. Dr. Schilling said that for the small rockets the time of arrival is not very important, but for the large rockets the nitric should arrive first. There is a double danger if either liquid is allowed to accumulate because an accumulation of fuel may go off suddenly, while an accumulation of acid may nitrate the fuel on arrival and form an explosive compound.

The accuracy of the metal burster diaphragms is uncertain and there may be a variation of as much as 1 sec in the timing of the bursters. Dr. Heller said that from the time you fire the firing valve to obtain ignition was about 5 secs*, while from the ignition time to full thrust would be about 4 secs.

10. Testing

Instruments and valves were tested for their behaviour over one years storage by keeping them for 24 hours in a BIER-DAVIS bomb filled with oxygen at 25 atmospheres (gauge). This English apparatus was reputed to give the equivalent in 24 hours of one years life in storage. (ENG.PASTWA)

The Wasserfal was tested statically by mounting it vertically in a parallelogram so that it was free to move against a rigidly held MESS-BIEGEL. This consisted of an oval steel ring. The minor axis contracted when subjected to the thrust of the rocket The dimensions of an air gap were thereby altered, modifying the induction in a coil mounted around the bar which formed the minor axis of the oval ring. This device was operated at 500 cycles, gave a deflection of ½mm for a thrust of 8 tonnes and was reputed to register the thrust to an accuracy of ± 1 to 2%.

Most of the instruments used for testing the Wasserfal were the same as for A.4, but special instruments had to be made for use in acid. (ENG. SCHULLER)

The Wasserfal was fired from a mobile circular platform carried on four wheels and pulled by tractor. Eng. Tütz saw a test firing of the Wasserfal and said that the combustion was rather spasmodic.

*It is difficult to believe that such a long time could be tolerated for an anti-aircraft weapon and it is possible that the true time is 0.5 secs. The exhaust gases were a reddish-yellow colour. It swayed slightly as it went up.

TAIFUN.

This bi-liquid rocket was reputed to be fired in groups of 65 from a launching machine known as the Dobgërat named after General Dornberger the inventor. War head 500gm with contact fuse, range 12Km (can be vertical), maximum velocity 1200m/sec. The projectile is approximately 2.1m long and 10cm in diameter. The greater part is taken up with the fuel tanks which contain Vizol and acid. The acid is housed in a central aluminimum tank, capacity approximately 6 litres, while the Vizol is contained in the annula space between the outside tank and the shell of the skin. This has a capacity of approximately 2.75 litres. As the gravity of the acid is 1.59 the tank when full would hold 9.4kg, while the fuel tank, assuming a gravity of 0.91, would hold 2.5kg. The walls of both tanks were 1mm thick. The acid tank is supported in the rocket shell by two aluminimum end plates bolted to its end flanges. These end plates are perforated so as to connect the fuel tanks at the upper end to the cartridge pot and at the lower end to the liquid sprays. It is probable that at both ends a rupturing diaphragm of aluminimum covers the holes in the two end plates.

Behind a solid steel nose there is a hollow chamber for the 500gm of explosive, the fuse and the igniting device for the cartridge which, when burning, provides the gas to expel the liquids.

The combustion chamber and venturi are made of mild steel mostly 1mm thick, but the thickness increases at the venturi throat to 2½ to 3 mm. At the end of 2 secs operation, the temperature of the venturi reached 300 to 400°C. They could use a venturi experimentally for 5 runs, after which it had to be renewed. The sprayer was not found, but it was described as being in three parts and to resemble the rose from a watering can. (ENG SIEFERT)

It was reported that in the early stages of development they had repeated trouble due to the venturi burning. (ENG. FINZEL) The design of the stabilizing fins was modified several times. They had tried fins of different lengths (ENG. SIEFERT)

Total fuel content is possibly about 12Kg or, if one allows a 10% ullage space to prevent bursting of the diaphragms in storage, the workable fuel would be 11kg. As the firing lasted between two and three secs the mass flow of fuels must have been between 3.7 and 4.4Kg/sec. The thrust is described as being between 600 and

1000kg. Unless the design of the jets and jet plate added appreciably to the volume of the combustion chamber, the L* with a throat of 45mm dia is very low, being in the order of 27". Prof.v.Braun said that they sacrificed the combustion chamber to get larger fuel tanks and accepted a S.I. as low as 160lb/lb/sec. The empty weight including war head and cartridge would be about 12kg, so the proportion of liquids carried would be about 0.48:1. With such a small combustion chamber complete reaction must have been difficult, but if they obtained a S.I. of 180 the thrust would be somewhere between 660 and 800 kg. Mention was made of an acceleration of 60g, but this must have been at the moment of "all burnt". The starting acceleration possibly did not exceed 35g.

Testing

When testing a Taifun on a static test bed, they often used nitrogen for expulsion. The thrust was measured by hydraulic piston. There was no evidence that the Taifun has passed beyond the experimental stage. (DR.SCHILLING)

B.M.W.

I visited the works of the Bayeriche Machine Werkes near Munich with Lt.Ozol, Sqd/L. E.J.A.Kenny, Dr.H.A.Leibhafsky (U.S. Ordnance, and G.E. Co.) On the way we picked up Dr.Hommersath the Chief Chemist. In this factory they concentrated their research on the use of nitric acid and mixed acids as the oxidant. They used hydrazine and a number of amines as the fuel. The acid was known as Salbei and the fuel as Tonka. Dr.Hommersath said that they had tried 6,000 combinations of acid and fuels.

We inspected 12 pairs of combustion test chambers each pair having a control room. Each test chamber had two explosion proof windows. These windows consisted of two panes of submarine glass each 10cm. thick. Each pane was made of layers of glass placed alternatively at right angles to each other so as to avoid distortion. The two panes were about 12" apart, the inter-space being electrically heated and containing a drying agent. The walls of the test chambers were reinforced concrete 3 feet thick. The inspection windows during a test were covered by expanded metal counterweighted grills which were lowered into place. The chamber was lit by four floodlamps, one in each corner protected by metal grills. The object of the metal grills in front of the windows was not to protect the observer, but to keep the glass of the windows from being damaged by flying fragments. In all their work on liquid reaction chambers they have had many explosions, but have only had one casualty and that apparently was due to his own fault.

The exhaust end of each chamber was open to atmosphere, but about 30 feet away from the test chambers and parallel to them was a large brick flue, at one end of which there was a square brick stack with a compressed air injector. A mobile telescopic cylindrical flue could be wheeled into place opposite the open end of a test chamber, so that the products of the reaction could be led into the brick flue and hence to the stack. In the test chambers were thrust motors carrying cradles and thrust measuring gear of varied types and sizes according to the kind of thrust motor to be tested. There were small cradles for the double coil X.548. When tested these had a mass flow of 2 litres of fuel plus 8 litres of acid in a firing time of 20 to 22 secs. The average ratio of oxidant to fuel was 5:1 and the mass flow about 0.8Kg/sec. The liquid fuels were expelled by nitrogen pressure at 40 atmospheres and the combustion chamber worked at 35 atmospheres. Dr.Hommersath said that the impulse was 1,000k/tonne/sec and also mentioned 1200 to 1400 k/tonne/sec. It is difficult to collate these figures with other known methods of specifying the impulse. Dr. von Braun at Peenemünde could not understand them, but suggested that they might represent the area of a thrust-time curve. If the mass flow was 0.8k/sec. and the specific impulse 180lb/lb/sec., the thrust would be 144Kg. which, over 21 secs., would give 3000k/secs. It is possible that in these figures there is some factor concerning the all up weight of the appliance. A similar curious figure was given for the larger model, the X.558, for which Dr.Hemmersath described the impulse as being 10,000 to 14,000 k/tonne/sec.

Dr. Hemmersath said that not all the pairs of fluids used were "hypergol", that is auto-igniting with each other, in which case they used independent means to initiate ignition. These are:-

a) Firework (Powder).
b) Electric spark.
c) A pair of fluids which reacted when brought into contact.

In this station besides testing X.548 and X.558 they ran the thrust motors for the Me.163 on acid and Tonka and there is some evidence that they also ran A.4 combustion chambers, Wasserfal and Enzian reaction chambers on these fuels.

There was a large test chamber for the calibration of acid and fuel jets. There was also facilities for testing thrust motors in any chamber from control tanks supported on accurate weighing machine.

Each control chamber had two complete sets of instruments and control gear, one for each test chamber. The chief instrument was that which recorded the thrust (as measured by hydraulic thrust piston) and the pressure in the combustion chamber. The control chamber also contained a great amount of electrical gear and indicators, so that continuity tests could be easily carried out on units before firing. In the control chambers were also the high pressure bottles and control gear for pressurizing liquid vessels in the rocket units. Towards the end of the test chambers was a large chamber in which spherical stainless steel or aluminimum tanks about 12-14 feet in diameter. These were suspended from the roof. There was also elsewhere mobile tanks for transporting nitric acid and H_2O_2.

I was given to understand that this factory, which also makes Turbo Jet Aricraft engines had been already covered by a C.A.F.T. team and by an investigation team, but if this is not the case, I consider it would be a first class target which should be thoroughly examined. This examination will be helped if Dr.Hommersath and the other principal members of the research team, whom are apparently dispersed, are brought together and induced to part with the relevant information.

While interrogating the Peenemünde staff we found an Engineer Johann Tütz who had worked in 1940 to 1942 at the B.M.W., Berlin. There he was concerned with the design of the following rocket weapons:-

(a)	A.T.O. Units	Methyl alcohol plus nitric acid (self-lighting). Thrust 1 tonne for 30 secs. Liquids expelled by gas pressure from a combustion chamber. After use the units were dropped in with a parachute. Eng. Tütz could not say whether these units were used operationally.
(b)	Glide Bomb	This was the same as the H_2O_2motor for HS.293, but used acid and fuel.
(c)	Rockets	They were planning to build rockets using acid and fuel as the propellent.

SURVEY OF DEVELOPMENT OF LIQUID ROCKETS IN GERMANY AND THEIR FUTURE PROSPECTS

by Prof. W. von Braun.

We consider the A.4 stratospheric rocket developed by us (known to the public as V-2) as an intermediate solution conditioned by this war, a solution which still has certain inherent short comings, and which compares with the future possibilities of the art about in the same way as a bomber plane of the last war compares with a modern bomber or large passenger plane.

We are convinced that a complete mastery of the art of rockets will change conditions in the world in much the same way as did the mastery of aeronautics and that this change will apply both to the civilian and the military aspects of their use. We know on the other hand from our past experience that a complete mastery of the art is only possible if large sums of money are expended on its development and that setbacks and sacrifices will occur, such as was in the case in the development of aircraft.

A few private groups of inventors started serious work on liquid rocket development in Germany in the years 1929-1930. One of those groups, called "Rocket Flying Field Berlin", located at Berlin-Reinickendorf, had Prof. Dr. von Braun as a student among its members. Simple fundamental tests with rocket combustion chambers were carried out there, and small uncontrolled liquid rockets were fired, which reached heights up to 1,000 meters, and landed by means of a parachute. At the end of 1932 the work of these groups were slowed down by lack of cash, but the Army Weapons Department was interested in carrying on the work, and took over the services first of Prof. von Braun, and later of most of the other engineers.

This special division of the Army Weapons Department was put under the direction of Dr.Ing. h.c. DORNBERGER, and the first rockets developed by them were designed solely for experimental purposes, and were of no military value. In 1934, liquid rockets of the "A-2" type were successfully tried out. They had a thrust of 300kg., were directly stabilized by means of a large gyro, and reached a height of approximately 2,000 meters. In 1938 the first trials were carried out with liquid rockets of the "A-3" and A-5" types, which were fitted with an automatic control system and rudders in the gas stream. These rockets reached a height of 12km when fired vertically, and had a range of 18km when fired at an angle. They could land in both cases by means of parachutes, and be used again.

In view of the successful results achieved with liquid rockets, it was decided in 1936 to begin with the construction of a large experimental establishment for rocket development at Peenemünde on the Baltic. It was already recognized at that time that the development of rocket showed great promise in the field of aeronautics as well as in that of artillery, and it was therefore decided to build two separate establishments at Peenemünde, one for the Army and one for the Air Force, which are two distinct branches of the "Wehrmacht" in Germany. At Peenemünde-Ost, comprehensive test beds and work-shop facilities were set up for the construction and testing of rocket drives and controls, whilst at Peenemünde-West an airfield was built for testing rocket aircraft, and pilotless rocket propelled aircraft, as well as auxiliary drives for standard aircraft, such as rocket assisted take off devices. The cost of construction of the complete installation at Peenemünde totalled approximately 300,000,000 Marks after completion. This close proximity of the rocket development work to the aeronautical development side is one of the principal reasons for the success of the work undertaken at Peenemünde.

The following considerations were decisive in the choice of Peenemünde, and these considerations will always be important when choosing a site for rocket development work.

a) Secluded position, far away from large towns (Safety during launching, nuisance caused by noise of large test beds).

b) Favourable weather conditions (during firing and flight trials of rocket and rocket aircraft blue skies are always desirable).

c) Reasonably satisfactory communications. The development work necessitates constant close contact between development engineers and certain branches of industry.

The successful experimental rocket "A-5", previously mentioned had a thrust of 1500kg lasting 45 seconds. Basing on the results obtained with the rocket, the order was given to develop a long distance rocket with a range of 250km., as high an accuracy as possible, and a warhead weighing 1,000kg. This rocket, known as "A.4", was first launched successfully in October 1942. The "A.4" has a thrust of 25 tons, for combustion period of 68 seconds max. It is fired vertically from a firing table, without guides of any sort, as was the case with all the previous rockets. The steering of the rocket to an inclined position is effected by means of a "programme" apparatus. The lateral direction is determined by the exact setting of a turn-table on the firing table. The exact range is determined by shutting off the propulsion unit upon reaching a previously calculated speed.

The development of the "A.4" required a great number of preliminary scientific investigations, the most important of which are briefly outlined below:

a) Wind tunnel tests at all ranges of air speeds between 0 and 1500 meters per second. During these tests, such factors as the stability of the rocket, the distribution of the air pressure, the working of the rudders and several moves were investigated, apart from the drag measurements, both with and without exhaust gas stream. Both the supersonic wind tunnel and the measuring methods had to be developed over a period of years of hard work.

b) Test bed investigations on the combustion chamber of the rocket, and on the complete propulsion unit. This too necessitated the development of appropriate test beds and measuring methods.

c) Investigations connected with the steering of the rocket at all ranges of airspeeds covered by the rocket. For this purpose, a special technique of models, reproducing the attitude of the rocket in flight, was developed.

d) Development of measuring methods for plotting the complete flight path of the rocket.

e) Investigation connected with the influence of the exhaust gas stream on the wireless communication between rocket and ground, etc.

In view of the increasing strength of the numbers of flight aircraft in England, and the resulting increased losses of bombers operating against England, orders were given at the end of 1942 to produce the "A.4" rocket in quantities. The accuracy of aim was still unsatisfactory, and limited the use of the rocket to large area targets, foremost of which was London. Nevertheless, some 60 to 65,000 drawing modifications were required before the first experimental "A.4" rocket became a real series production job. This indicates how many absolutely new problems arose during the trials of the "A.4", which was subjected to hither unknown physical conditions.

Meanwhile the development side was attempting to improve the accuracy of aim of the rocket. To this end, radio guide beam devices were developed to improve the lateral direction, and improved propulsion unit cut off devices to reduce the dispersion in range. These improvements however were incorporated operationally on a small scale only, and were in use chiefly in the attack on the harbour at Antwerp.

The original objective of further development was to produce long distance rockets of greater range. It should be noted here that the maximum ranges up to 480km. were achieved thanks to certain improvements, which however never came into operational use.

Certain A.4 rockets were used to carry out vertical trajectory trials, and a maximum ceiling of 172 km was reached during these trials.

It was planned in the spring of 1945 to fire vertically from an island situated near Peenemünde a few A.4 rockets equipped with special instruments for research into the top layer of the atmosphere. The measuring instruments were put in a watertight container capable of floating, which was to have descended by parachute. This project, all preparations for which were completed, could not be carried out on account of military events. It could be done in a short time however, with some of the A.4 rockets still in hand.

The problem of increasing the range of the A.4. after completion of the A.4 development programme could only be carried on at a greatly reduced rate, as the development of a guided anti-aircraft rocket was given first priority and absorbed much of the personnel, in consequence of the increasing air superiority of the Allies. A rocket for this purpose was developed at Peenemünde, bearing the code name "Wassorfal".

This rocket was also propelled by liquid fuel, and could be guided by radio from the ground on to flying targets. Various successful tests were carried out, but series production of the weapon was not achieved.

A further development of the "A.4" long distance rocket is the "A.9", on which work was done as far as the priority work on "Wasserfal" would allow. The propulsion unit was the same as for A.4. The A.9. rocket however had wings, which enabled it to glide through the stratosphere. This enables the flight path to be increased to such an extent that the range of the A.9 was nearly double that of the A.4, v.e. approx. 600km., notwithstanding the fact that the fuel consumption of the A.9 was no greater than that of the A.4 owing to development could not be completed on account of the end of the war. Special control devices would have given the A9 at least the same accuracy as the A.4. It was proposed that the weapon should go into a vertical dive at the end of the glide, similar to that of the V.1.

As a further development, it was intended to design the A.9 winged rocket to carry a crew. For that purpose the rocket was to be equipped with a retracting undercarriage, a pressurized cabin for the pilot, manually operated steering gear for use when landing, and special aerodynamic aids to landing. The landing speed of this piloted A.9 rocket would have been as low as 160km per hour, as it would have contained very little fuel on landing, and would consequently have been light. This piloted A.9 rocket would cover a distance of 600km in approx. 17 minutes.

The range of the A.9, both in the piloted and the pilotless versions, could be increased considerably if the propulsion unit were switched on only after the rocket had attained a certain initial velocity There were two possible ways of achieving this end.

1) Use of a long catapult with only a slight gradient, which would have given the rocket an initial velocity of approx. 350m/sec. There was experience of this type of catapult to hand at Peenemünde, as such a catapult developed by an industrial firm for launching the V.1, was tried out at Peenemünde. Experience showed that catapults could be built for launching at supersonic speed. These high speeds are essential for rockets such as A.9, because the rocket is completely filled with fuel at the start and would not fly if it left the catapult at lower speeds.

2) Development of a large assisted take off rocket of 200 tons thrust, on which the A.9 rocket would be mounted, and which would give the latter an initial velocity of 1200 meters per second. After the assisted take off rocket has exhausted its fuel, the A.9 would become separated from it, and its own propulsion unit would be switched on. The maximum speed of the A.9 at the end of its power drive under these condition would be approx. 2800 meters per second, which would mean that this combination could give the A.9 a range of approx. 5000 km., both in the piloted and the pilotless versions. The large assisted take off rocket, called A.10, was to be equipped with air brakes and a special parachute, which would have enabled it to be used again after alighting on water.

It was proposed to launch the A9/A10 combination vertically this obviating the necessity of erecting large ground launching devices.

In the more distant future, the development of liquid rockets offer in our opinion the following possibilities, some of which are of tremendous significance:

1) Development of long range commercial planes and long range bombers for ultra high speeds. The flight duration of a fast rocket aircraft going from Europe to America would be approx. 40 minutes. It would even be possible to build very long range bombers, which would turn round at supersonic speeds in a very wide curve after having released their bombs, and return in an glide to land at their point of departure. The high speed of such aircraft would make defence against it ineffective with present day means.

2) Construction of multistage piloted rockets, which would reach a maximum speed of over 7500 meters per second outside the earth's atmosphere. At such speeds the rocket would not return to earth, as gravity and centrifugal force would balance each other out. In such a case the rocket would fly along a gravitational trajectory, without any power, around the earth in the same way as the moon. According to the distance of the trajectory from the earth, the rocket would complete one circuit around the earth in any time between

1 1/2 hours and several days. The whole of the earth's surface could be continuously observed from such a rocket. The crew could be equipped with very powerful telescopes, and be able to observe even small objects, such as ships, icebergs, troup movements, constructional work etc. They could also carry out physical and astronomical research on problems which could only be tackled at that altitude, due to the absence of the atmosphere. The importance of such an "observation platform" in the scientific, economic and military spheres is obvious. When the crew of the rocket want to return to earth, all they need to do is to reduce the speed of the rocket slightly, which can be done by rocket propulsion. The rocket then entered the upper layers of the atmosphere tangentically, and its speed is gradually reduced by friction. Finally it can land like an ordinary aeroplane by means of wings and auxiliary gear. It would also be possible to relieve the crew and provision the "observation platform" by means of another rocket, which would climb up to the platform and pull up beside it.

3) Instead of having a rocket set up an "observation platform" outside the earth, it would be possible later on to build a station specially for the purpose, and send the components up into the interstellar spaces by means of rockets, to be erected there. The erection could be easy, as the components would have no weight in the state of free gravitation. The work would be done by men who would float in space, wearing divers suit, and who could move at will in space by means of small rocket propulsion units, the nozzles of which they would point in the required direction.

4) According to a proposal by the German Scientist Prof.Oberth, an observation station of this Type could be equipped with an enormous mirror, consisting of a huge net of steel wire on to which thin metal foils could be suspended. A mirror of this nature could have a diameter of many kilometers, and its component facets could be controlled by the station which would enable the heat and light of the sun to be concentrated on selected points of the earth's surface. This would enable large towns for instance to get sunlight during the evening hours. The weather, too, can be influenced by systematic concentration of the sun's rays on to certain regions. Rain could be induced to fall on regions hit by drought, by concentrating the sun's rays on to distant lakes and seas, and increasing their evaporation. The clouds thus formed could be driven to the required spot by influencing the centres of low and high pressure through radiation from other facets of the mirror. If the mirror is made large enough, and it could be of extremely light construction, it would even appear possible to generate deadly degrees of heat at certain spots of the earth's surface.

5) When the art of rockets is developed further, it will be possible to go to other planets, first of all the moon. The scientific importance of such trips is obvious. In this connection, we see possibilities in the combination of the work done all over the world in connection with the harnessing of atomic energy together with the development of rockets, the consequence of which cannot yet be fully predicted.

To conclude, we think after what has been said above that a well planned development of the art of rockets will have revolutionary consequences in the scientific and military spheres, as in that of civilization generally, much in the same way as the development of aviation has brought revolutionary changes in the last 50 years.

A prophecy regarding the development of aviation, made in 1895 and covering the next 50 years, and corresponding to the actual facts, would have appeared at least as phantastic then as does the present forecast of the possibilities of rocket development.

In the same way as the development of aviation was not the work of a single man, but became possible thanks to the combined experience of many thousands of specialists, who concentrated exclusively on this one branch of science for years, so the development of the art of rockets will require a systematic effort by all specialists who have gained experience on this subject.

PROJECTILES SERIES "A" (LIQUID OXYGEN AND ALCOHOL)

NUMBER	YEAR	DIA. CMS	LENGTH M.	THRUST KG	TOTAL WT	FUEL	POWER TIME SECS	NOTES
1	1933	30	1.4	300	150	40	16	Directly stabilized by one large gyro (weight 40Kg) in the nose. Never launched. Many difficulties. N_2 expulsion. Intended to launch from a table vertically. S.I. 143
2	1934	30	1.4	300	150	40	16	As in A.1 but gyro placed in the centre. Successfully launched to 2000 metres. Launched vertically from table. S.I. 143
3	1938	75	7.6	1,500	750	450	45	Shape similar to A.4, launched vertically from table. Auto steering and rudders in gas stream. Did not obtain supersonic speed. Reached 1200m. in height. S.I. 167
4	1940 1942	1700	14	25,000	12,500	8000	68 max	Range 250 Kms. Warhead 1000Kg. Program motor to bend over the trajectory. Vertical launch. Bearing from launching table. Range by fuel cut off. S.I. 208
5	1938	75	7.6	1,500	750	450	45	Experimental unit. Prototype of A.4. First model to use graphite blades. Could be landed by parachute and used again. Maximum range with slanting launch 18 Kms.
9	1945	1700	14	25,000	13,000	8000	68 max	As A.4 but with wings permitting a glide in the stratosphere. Total range increased to about 600 Kms. Same accuracy as A.4 Vertical dive at end of glide. Also one man crew so retractable undercarriage. Pressure cabin and hand control for landing at 140-160metres/hr. 80% of construction as in A.4.
[illegible]								Designed but not constructed. A.5 did not reach supersonic speeds. Design modified to give higher speed and considerably different from A.5 so given new number.
7	1941	75	7.6	1,500	800	500	45	Designed only. A.5 plus wings. Launched horizontally from aircraft to obtain experimental data.
10		350	8	200,000	87,000	62000	50	Project only. Calculations completed for a unit to be used as a starting device for A.9. When A.9 and A.10 reach 1200m/sec, A.10 is jettisoned and descends by parachute. A.9 continues and reaches an "all burnt" velocity of 2800m/sec. Then A.9 glides. Total range A.9 + A.10 = 5000km.

GARMISCH 23.5.45.

175A/PD.

Alfred Bachmann

Electrical development engineer. Came from T.H. Berlin and worked originally on eliminating disturbances on transmission lines. Afterwards subject was employed at Siemens-Schuckert, contract administration. Later he was with the "Reichsgruppe Energiewirtschaft" on the planning of power generation throughout Germany. Military Service from February 1940 until January 1942, participated at the French campaign. Then at Peenemünde he worked on the electrical ground installations for the test stands.

Herbert Bergeler

Worked on auxiliary gadgets for the V-2 (A4). Worked on solenoid valves, pneumatic valves and propellant valves. All valves had to be constructed at Peenemünde, could not be bought. For O-rings (sleeves) some type of rubber was used, even for the liquid oxygen.

Ernst Bippard

Built the body of the V-2. Was airplane constructor. Got all the daté on the stresses and had to build the proper outer casings for the V-2. Essentially three types of steel sheets were used (Fliegwerkstoffe St V11 23).

Hermann Buhl

Analyzed the data obtained from the survey of the path to determine the proper characteristics of the projectile and of the jet motor for the achievement of best range and smallest weight. (Did not work on A9 and"Wasserfall")

INTERROGATION OF RUDOLF BÄRWALD

BY: H.A.Leibhafsky, J Iball, G.T.Gollen at Garmisch

DATED: 22 May 1945.

Was in charge of motor tanks for O_2

Tanks contained 6700 litres.

Tank insulated with 5 cms glass wool (Hyporka) and outer sheet - metal cover.

Loss 350 litres per ~~day~~ 24 hour day.

Sometimes got his $L.O_2$ from the factory and sometimes by pressure from rail car.

Transfer by portable engine driven pump which could be carried by 2 men.

$L.O_2$ transferred to A 4 rigid 7 cms I.D. pipe covered with woven insulation.

INTERROGATION OF:

Prof. von Braun.
Dr. Steinhof.
Dr. Kirchstein.
Dr. Mühlner

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by

Partenkirschen, May 16, 1945.

The above men were interrogated with a view to obtaining information on the radio aspects of A-4 and Wasserfall as well as homing systems and proximity fuses.

The histories and responsibilities of these men are covered in Flight-Lieutenant Block's report. Briefly, Steinhof was answerable directly to von Braun, Kirchstein was responsible for the range control apparatus under Steinhof, and Mühler was in charge of the Doffler velocity determining equipment under Kirchstein.

All of the men talked freely and their stories were generally consistent. To obtain accurate detailed information it was necessary to go down to the level of Mühlner.

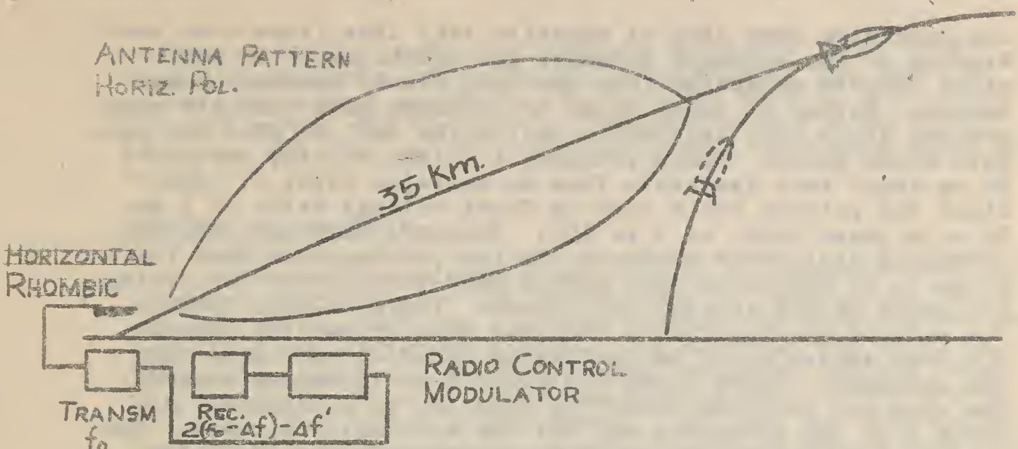
The following pages represent an integration of the material obtained from all four men. When necessary, reference is made to the source of the material.

Dr. Ing. Steinhof worked directly under Prof. von Braun and was in charge of all problems on the A-4 and Wasserfall relating to (1) Electrical systems (2) Flight mechanics (3) Automatic steering and (4) Free flight testing. For a short period he was in charge of static testing also, but was relieved of this by Dr. Thiel. Although he was in charge of these projects on Wasserfall, he concentrated mainly on the A-4, acting more in an advisory capacity to the people under him on Wasserfall.

Brennschluss. During the early stages of the A-4 development, much thought and time was given to the problem of accurate range control by the method of stopping the rocket engine (Brennschluss) at the appropriate time in the trajectory. Since

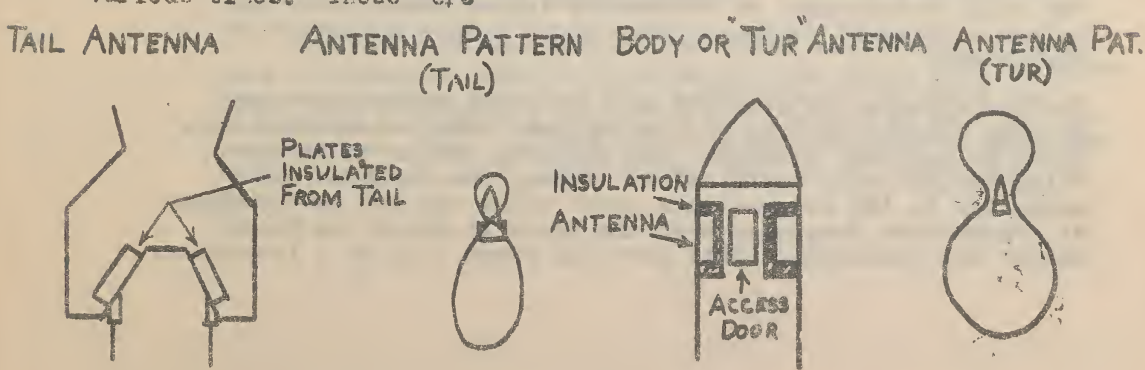
Range = $f(v_x, v_y, x, y)$
where x and y are the coordinates of the trajectory at the cut-off point,

it was at first attempted to devise some method which would function on the basis of all four of these variables. This proved to be too difficult a problem to solve in the time available so a compromise was made. The component of velocity tangential to the trajectory at the cut-off point was used to determine the cut-off point. A radio Doffler system adapted itself very well to this compromise. A CW transmitter of about 800 watts power output was placement a point on the ground where the tangent line intersects.



The ground transmitting antennas consisted of a horizontal rhombic so placed above the ground that its horizontal polarization pattern centered about the tangent line. This made detection at distances beyond 25 km on the ground practically impossible. The received frequency $2(fo-f)-f'$ was beaten against 2fo and then passed through a filter centered at about 500 cycles/second with a band width of about 50 cycles/second. The narrowness of this band was considered an important anti-jam feature. The output of this filter triggered a relay which in turn triggered off the radio-control signal. This control signal consisted of a combination of five modulation frequencies in a specific time sequence (an AIS report completely describing this system was published some time ago). This command signal is then used to modulate the same transmitter used for velocity determination. However, in this operation the transmitter output was only 200 watts. The basic frequency used was 30 mc. with possible variations of .

On the A-4 three different types of antennas were used at various times. These were



The tail antennas consist either a pair of dipoles fed in opposite phase one potruding from each of opposite tail fins (thus four such dipoles or two balanced antennas are possible) or of two metal inserts separated from the tail fin by insulating material. Either of these types of antennas give much the same pattern since they apparently excite the tail to give the pattern shown above. These antennas are (the dipoles are about 30 cm long) very desirable from an anti-jam point of view since the pattern has a back to front voltage ratio of 1 to 10 or a power ratio of 1 to 100. However, they have the disadvantage that their proximity to the jet requires that radiation to or from them must always pass through the disturbing influence of the ionized jet stream. (More on this later). The antenna on the forward body was made by setting two of the four access doors on insulating material and using them for antennas. These doors are about 1 to 1½ meters square. The size and position (provided symmetry is maintained) affects only the impedance and not the resonant frequency. The pattern of this antenna is less desirable from an anti-jam point of view since it has a back to front voltage ratio of only about 1 to 2, but it is more desirable because of its position with respect to the jet stream. At the Brennschluss point, its position is as bad as that of the tail antenna as far as radiation through the jet stream is concerned. According to Dr. Muhlner, the trend of development was to have the Tur antenna serve as an antenna for transmit and receive Doffler, receive control, transmit Messgerat, and receive Leitstrahl, all in one antenna. Thus, all of the tail antennas could be removed.

Dr. Steinhof stated that they would like to have gone to higher frequencies in the missile to simplify the antenna problem but that the smaller power output obtainable from the same sized transmitter in the missile mitigated against this. Both Dr. Kirchstein and Dr. Muhlner stated that they were working on the Doffler system up to the end of the war. The original conception and development of the system was apparently made by Dr. Muhlner and Prof. Wohlman at Dresden. The final development at Peenemunde (since about 1942) involved a total of 50 men of whom about 8 were engineers or physicists.

The Tur antenna was utilized as both a receiving and transmitting antenna for the Doffler system. Two precautions were taken to keep the receiver from blocking and/or to prevent "ring around" self oscillation. First, the receiver was connected to the antenna at a point which was 90° out of phase at transmitter frequency with the point at which the transmitter was connected. This provided about a 10 to 1 isolation.

Second, a filter in the receiver line provided a further 5 to 1 attenuation of the transmitter frequency (an easy job since transmitter is on 2fo and receiver on fo). Thus, the voltage across the transmitter antenna terminals was about 10 volts and that at the receiver antenna terminals about 0.2 volts.

Jamming Precautions.

In the early developmental stages, the Germans were considerably worried over the possibility of jamming the Doffler system. To provide for this contingency, development was begun along two different angles. One solution was to go to a completely non-radio system for Brennschluss, and the other was to develop counter-countermeasures for the radio system. As a result of the former approach, the gyro and electrolytic integrating accelerometers were developed, produced, and used operationally. However, since several radio links, the Leitstrahlgerat and the telemetering (operational use of this was anticipated to improve the reliability and accuracy standards) were necessary for really satisfactory operation, work on the radio Doffler system was continued and anti-jam methods developed.

It was anticipated that as soon as any jamming difficulties were encountered, a panoramic search receiver would be incorporated in the A-4 and its output telemetered to the ground via the Doffler transmitter aboard the rocket. Such receivers had been developed by other agencies for communications and radar search purposes and were available. Thus, for example, a 20-80 mc receiver could have been quickly installed. Since no jamming was ever reported, this procedure was not resorted to.

A second anti-jam precaution, previously mentioned, was the narrow band filter on the ground to detect the proper Doffler frequency for Brennschluss.

Another anti-jam feature was under development to prevent blocking or capture by enemy signals which were stronger than the desired signal. This method involved using the difference frequency between the two signals to modulate the transmitter. More details and a circuit diagram of this are being prepared by Dr. Muhlner and will be included when received.

Some of the lesser known details of the system are summarized below:

fo = mc plus or minus 5%
CW ground transm. power = 800 Watts
Mod " " " = 200 "
CW rocket " " = 5-10 "
Rocket Doffler receiver sensitivity for saturation = 50 millivolts
Approx. signal received across rocket antenna terminals at Brennschluss ≅ 1-2 microvolts
Approx. signal received across ground antenna terminals at Brennschluss = 200 millivolts
Ground transmitter antenna -- rhombic
Polarization -- horizontal
Rocket tail antenna directivity -- 90% at half power points
Rocket tail antenna back to front ratio -- 10:1 (V)
Rocket Tur antenna back to front ratio --- 2:1 (V)
Length of tail antenna dipoles -- 30-40 cm

Test Procedure of Doffler system involved the transmission of a test signal from a small crystal controlled test transmitter known as Ziegelsteinsender. This signal would be received by the receiver on the rocket with the result that the transmitter would be triggered off. A measurement of the voltage across the antenna would then indicate if the entire chain was functioning. Obviously, this was only a "yes or no" test. To make this test, it was necessary for a man to climb up a ladder to make the antenna voltage measurement.

Leitstrahl Gerat.

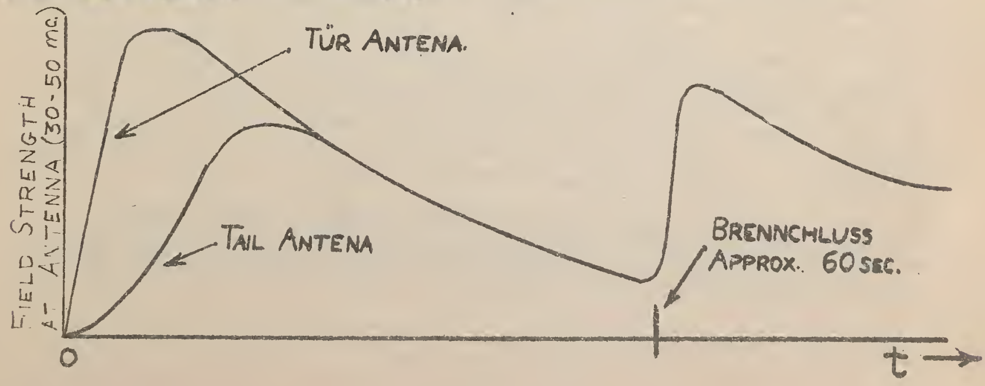
To obtain more accurate bearing control, a system was used which was developed in the middle '30s for blind approach and blind landing of aircraft. Dr. Steinhof stated that he did most of this early work himself. This equipment is known as the Leitstrahl Gerat. It involves setting up two very narrow crossed lobes by means of two half wave dipoles spaced 60 λ apart. By this means, an angular sensitivity of 1/200° is possible in the radio system. This is about four times the sensitivity of the gyro system. Obtaining high directivity by this method introduces, of course, the problem of many sharp side lobes of about 2° each. Precautions must be taken that the rocket does not fly up one of these other lobes. To avoid this, the Leitstrahl antenna is set 10 to 15 Km behind the launching point so that the desired lobes are broad at this point. The transmitter has a power output of 3 KW. Due to the antenna pattern and the propogation characteristics at this frequency, it was impossible to pick the signal up on the ground beyond 20 Km. The antenna for the Leitstrahl consisted of a pair of balanced dipoles in the tail, but the plan was to include it in the Tur antenna.

Wasserfall.

In the early work on Wasserfall, it was planned to use radar beam guiding. Telefunken had completed the development of a 500 mc radar for this purpose and had under development another at 1500 mc. Dr. Steinhof stated that frequencies in the 3-10 mc band were desired for this job, but the available powers at these frequencies were too low. He stated that such a system used with the A-4 should provide an accuracy of plus or minus 150 meters at 300 Km in both range and bearing. The A-4 was actually tested with the 500 mc radar using a 7 meter disk. These tests did not include actual steering, but rather the telemetering back of the information as received on the rocket. Kammler killed this phase of the project (i.e. radar guiding of A-4 and Wasserfall).

Ionization.

According to Steinhof, the radiation of 50 mc signals through the jet stream of the A-4 resulted in 90% absorption. At 500 mc, the absorption was 10%. In most of the test flights, of which there were hundreds, the field strength was measured at the missile and continuously telemetered to the ground where they were recorded. Dr. Kirchstein states that no reliable figures on attenuation were obtained, in some cases no attenuation was recorded and in others, the field strength was reduced by a factor of 5. Normal field strength measurements (i.e. without absorption paths) in themselves, are sufficiently variable to Steinhof, the variation of field strength with time (measured from the firing time) was somewhat as follows:



The low field strength at the start is due to the remoteness of the transmitter (about 8 Km) and also to the transmitting antenna pattern. The Tur antenna rises to a higher value because it is not shadowed by the ionized jet stream until late in the flight. At the Brennschluss point, the field strength rises sharply because of the elimination of the jet stream.

Inquiry was also made into the potential rise of the rocket itself due to the jet stream and also due to the rocket passing through ionized clouds. Steinhof and Kirchstein both stated that this problem was of great concern to them before they made any test firings. A test was made on the ground at Peenemunde by setting the A-4 on insulating material on the test stand. According to Kirchstein, these tests resulted in potential values of the order of 20,000 volts. The polarity was sometimes positive and sometimes negative. The tests were rather unreliable because of dust disturbance. Most of these details check with Vieweg's story. Kirchstein stated that Vieweg was involved in these tests. Steinhof brought out that the potential rise was of an appreciable value only during launching and Brennschluss. The potential rise due to any cause whatever apparently never rose to the point where corona discharge took place, since, if it had, it would have been detected in their field strength measurements which were continuously recorded over at least 3/4 of the flight (a distance of about 250 Km).

Telemetering.

Telemetering was of great importance in the development of the A-4 since it provided reliable checks on the design and operation. The equipment in use up to the present time consisted of an AM system with variable amplitude and multiple audio frequencies. By this method, four channels of continuous information was available. In addition, four more channels of off-on information was available by sending, at four other audio frequencies, short blips. The display on the ground consisted of two scopes each with four parallel line sweeps. One scope would present the four continuous channels, and the other the intermittant four channels. These displays would be photographed continuously during the flight. One flight would produce 8 rolls of recording, each roll being 70 meters long.

A second telemetering system was under development which was capable of transmitting 12 channels continuously and 12 channels off-on. Dr. Kirchstein had only seen this equipment once but was familiar with its operation. It was being developed by the Institute fur Schwingungs Forschung under Prof. Stoplein. The 12 continuous channels consisted of 12 audio frequencies; the intelligence on each channel being a frequency modulation. In addition, square wave modulation was superimposed so that for ½ cycle of the square wave, the carrier plus modulation would be on while for the other ½, it would be off. Discreet variations in the frequency of the square wave produced the 12 off-on channels.

Homing Systems and Proximity Fuzes.

Both Dr. Steinhof and Prof. von Braun were questioned regarding the development and use of homing systems and proximity fuzes. Steinhof knew very little about them, but von Braun had a general knowledge of all the systems which were contemplated for Wasserfall plus a few others. The desire was to develop a homing system which would also serve as a proximity fuze. Present development, however, concerned itself with one thing or the other and not a combination.

Sprotte.

This is a send-receive radar homing system being developed at Telefunken, Berlin, under Dr. Punge. About 8 weeks before the end of the war, Dr. Punge left Telefunken and went to work for DVL. Von Braun did not know if he took the development along. He can possibly be found somewhere near Ainring. This equipment, which is known as the H and V Gerat operates at about 23 cm. It would have been preferred to have it operate at 5 cm, but there was still considerable difficulty in getting sufficient power out of magnetrons at this frequency.

Further Interrogation of Steinhof, Kirchstein, and Muhlner.

by

R.H. Block & E.H. Krause 18 May 1945

A-4 Radio Equipment.

In addition to the command receiver, the Doffler receiver and the Doffler transmitter, a separate telemetering transmitter was carried in the test flights. To simplify this layout, there had been under development and was completed a single receiver for both the Doffler and command function. However, it was completed too late to make it worth changing the production.

The radio Doffler system was carried in all test flights as a check on other Brennschluss methods. Continuous recording of the Dofflerfrequency on the ground provided a check on all the systems. The accuracies on this basis were

Doffler System plus or minus 0.5%
Gyro int. accel. plus or minus 1.0%
Buchhold int. accel. plus or minus 0.5%

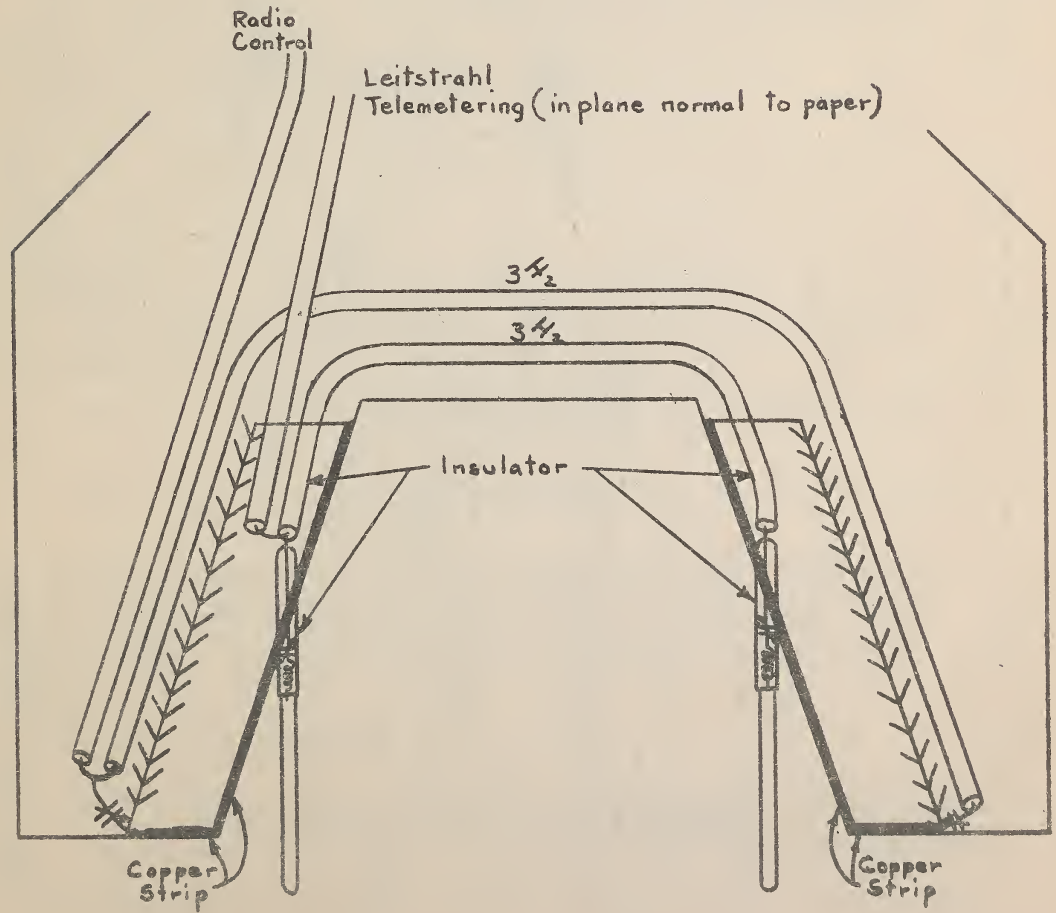
Sufficient trials had not yet been made on the Buchhold device to make its figure very reliable. Kirchstein felt that the radio system was the most accurate. Its complexity was by far the greatest, was subject to jamming and cost about ten times as much as the others.

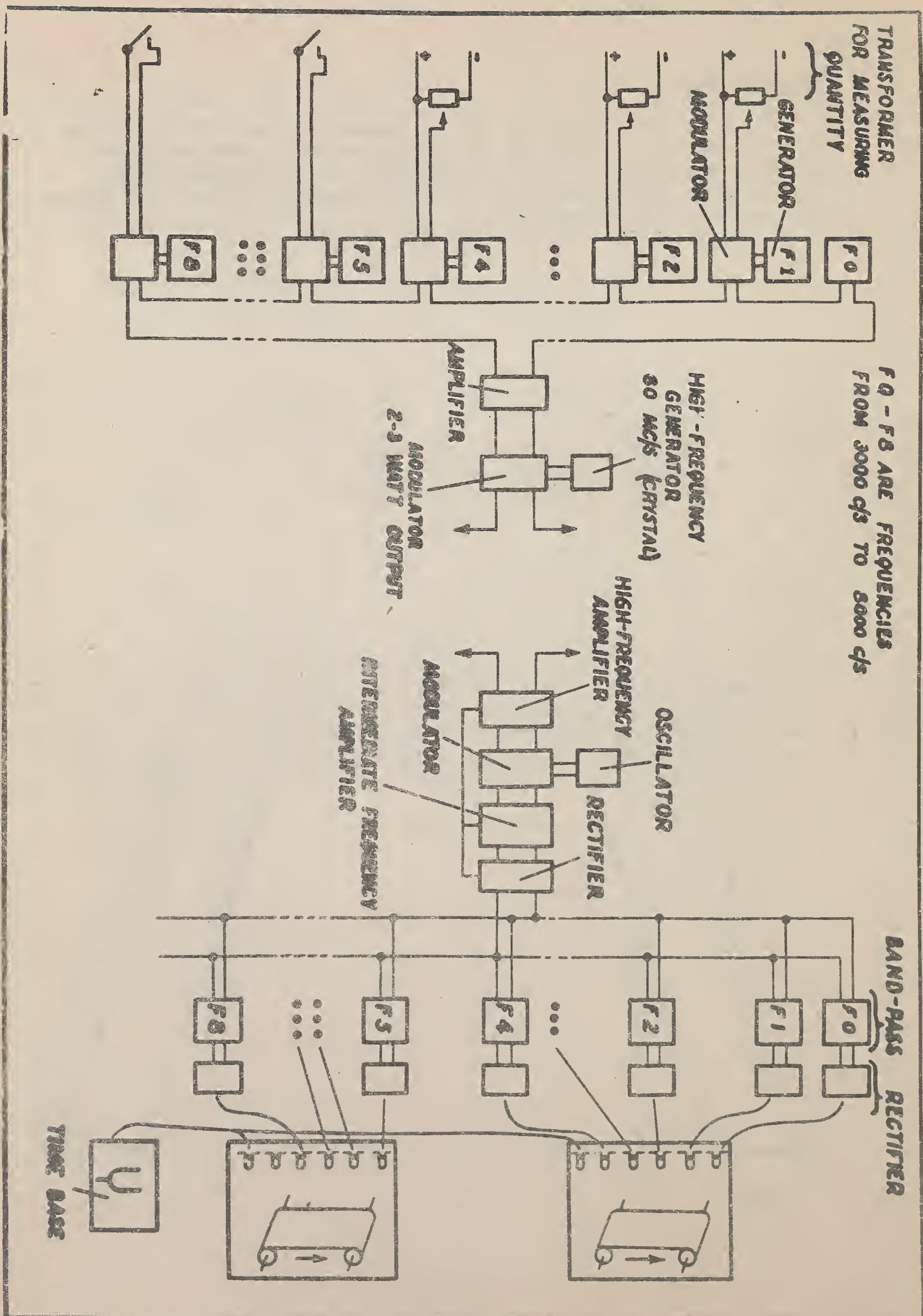
Telemetering.

The AM telemetering system was designed and built by Ober Lt. Eissnau who stayed in Bleicherode. Dr. Kirchstein was requested to draw up a circuit diagram of this system. It is shown on the following page of this report. The accuracy of the system was about 3%. The new FM system under development by Prof. Stopler was to be more accurate and have more range. The AM system suffered because eight channels allowed only about 10% modulation for each channel whereas this was not so in the FM system. The indicator system for the FM system was to be the same as for the AM for production reasons. Thus, six four channel indicators would be required.

A-4 Antennas.

Having previously obtained somewhat confused stories of the A-4 tail antennas, Dr. Muhlner was asked to draw as accurate a picture of these antennas as he could. This description is believed to be more accurate than that given in the May 16th report.

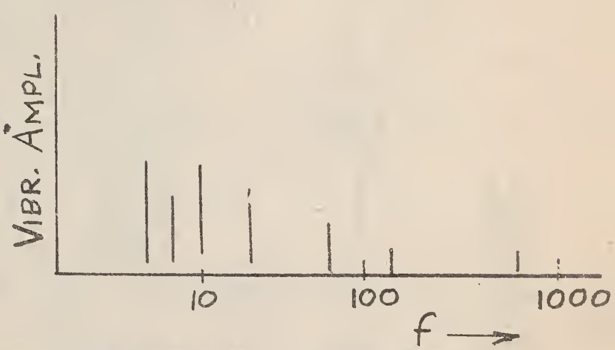



TRANSFORMER FOR MEASURING QUANTITY
GENERATOR
MODULATOR
F0
F1
F2
F4
F3
F8
F0 - F8 ARE FREQUENCIES FROM 3000 c/s TO 8000 c/s
HIGH-FREQUENCY GENERATOR 60 kc/s (CRYSTAL)
AMPLIFIER
MODULATOR 2-3 WATT OUTPUT
HIGH-FREQUENCY AMPLIFIER
OSCILLATOR
MODULATOR
RECTIFIER
INTERMEDIATE FREQUENCY AMPLIFIER
BAND-PASS
RECTIFIER
F0
F1
F2
F4
F3
F8
TIME BASE

The copper strip antenna was called Schleife antenna and the dipoles Stabe antenna. The Schleife was used for the radio control receiver; two of the Stabe were used for the Leitstrahl gerat and two (there was one on each of four fins) for telemetering. Contrary to Muhlner's opinion, Kirchstein felt that the tail antennas were more desirable because of the poor structural design of the doors. It was necessary to tune the tail antennas, but not the Tur to cover the six frequencies of 30 mc plus or minus 5%. This tuning was done by small variable ceramic condensors which were marked for three settings. The Stabe were capacative; the Schleife inductive.

Vibration.

Kirchstein stated that tests showed the vibration to peak at certain points as shown to the right. Here again they were very much concerned about the problem before any flights were made. When no trouble was found in the actual flights, they no longer worried about the problem. Hence, flight data on the subject is not very complete. On the basis of tests made, the equipment when shock mounted, had to pass the following specifications:



(a) 40 cyc/sec at 0.5 mm amplitude for 3 minutes tied to the test table.

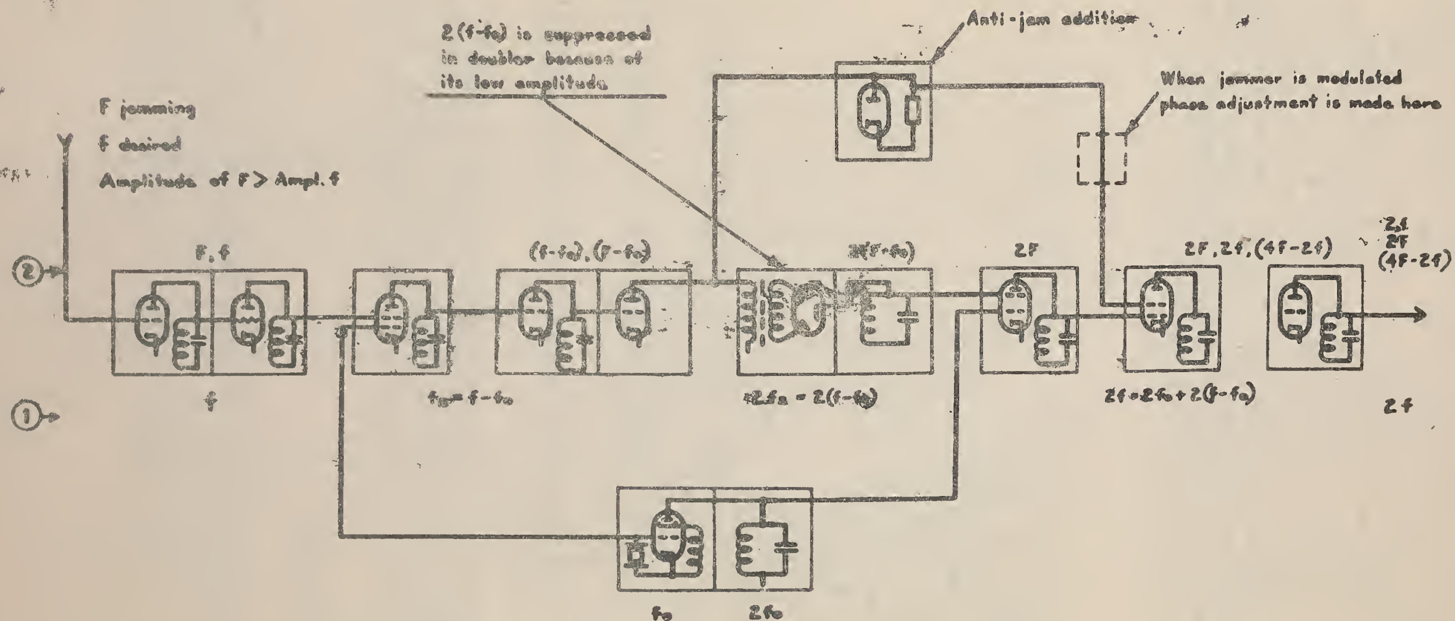
(b) 15 cyc/sec at 2 mm amplitude for 1 minute standing loose on the table.

The actual shock mounting consisted simply of four rubber disks about 3/4" diameter and ½" high. Further information on this vibration mounting can be obtained from Dipl. Ing. Hoehn or Dipl. Ing. Horn. Dr. Netzer should know about vibration in Wasserfall.

Doppler Anti-Jam Receiver.

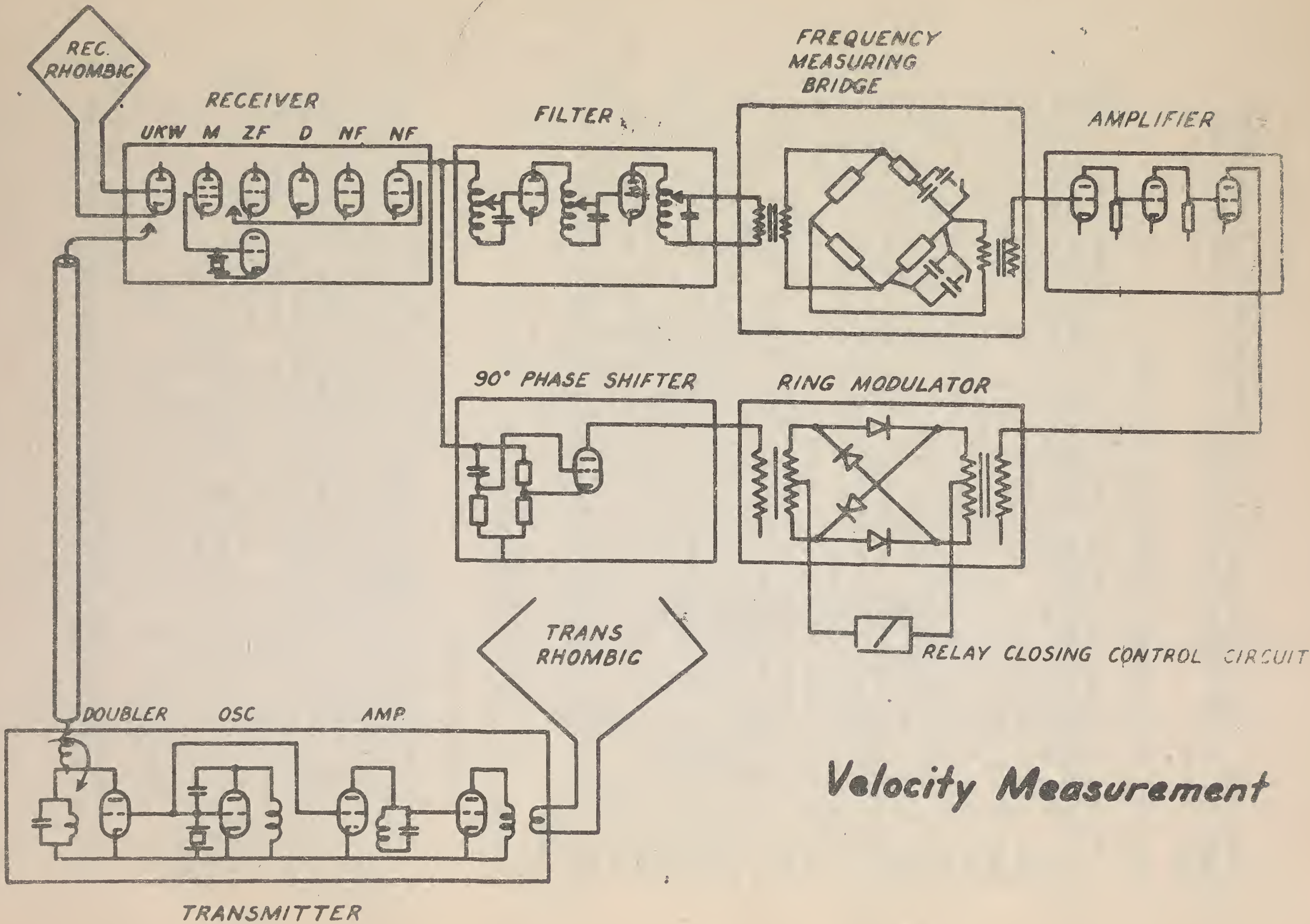
On the next page is shown the schematic circuit diagram of the Verdoppler with anti-jam circuit as drawn by Dr. Muhlner. Based on actual tests, this system was supposed to have worked through a CW jamming signal ten times larger than the desired signal and 20 times larger if the jamming signal was

Verdoppler



(1) With No Jamming

(2) With Jamming F



Velocity Measurement

modulated 100%. The small change required in a standard receiver would allow such a circuit to be quickly added when needed.

Velocity Measurement Equipment (Ground).

Dr. Muhlner was requested to draw a schematic diagram of the velocity measuring equipment. It is shown on page 15. The receiver and transmitter portions of the diagram are self explanatory. The output of the receiver is fed into a filter which is centored about the Doppler frequency (usually about 500) and has a bandwidth of about 50 This could be made narrower if a single Brennschluss were used. However, in later firings, two cut-offs were used. The first reduced the thrust from 25 tons to 8 tons, and the second cut it off entirely. This corresponded to about a 5% difference in velocity and hence the filter had to pass a broader frequency band. The filter fed into a Robinson bridge which was adjusted to null for the proper frequency. When two frequencies had to be measured, the first signal relay closing would be measured, the first signal relay closing would alter the bridge balance as shown. The null signal from the bridge feeds through an amplifier to the "ring modulater". The other side of the ring modulator is fed through a 90° phase shifter (to balance out the phase shift in the bridge). Then as the bridge current goes through a null, it reverses its phase which reverses the current in the ring modulator and closes the polarized relay which then automatically causes a control signal to be sent.

Homing Systems and FP Cont'd.

H and V Gerat.

An equipment under development by Telefunken for guiding of glide bombs (Hs 293 tec.) from the mother plane. The mother plane would track the ship in the H and V Gerat and then run the glide bomb down the beam. The transmitting antenna was a rotating dipole. The receiver had two antennas, the outputs of which were compared to provide bearing control. By using four antennas, the bomb could rotate (like the X-4) and still be properly steered. System was abandoned because (according to von Braun) the job could be done better by infra-red.

Windhund.

This is a home on Rotterdam system, being an extension of the CORFU-NAXOS development. It was being developed by

Telefunken under Dr. Runge. Some thought was given to, but no work done on the application of Windhund to a proximity fuze.

Madrid

An IR homing system under development by the KEPKA company in VIENNA. Von Braun knew little about this and thought very little of the firm.

Marabu.

A proximity fuze being developed by Siemens at Hackenfelder near Berlin. The company moved somewhere into Western Germany. A transmitter in the head of the missile sends out pulses while another antenna in the tail receives the echo. When the echo reaches a given strength, the fuze is fired. Range is supposed to be 30 meters or less.

Miessa.

A passive accoustic proximity fuze under development by Deutsher Reichspost Forschung at Machnow near Berlin. This same firm also had under development a radio Doppler PF.

? .

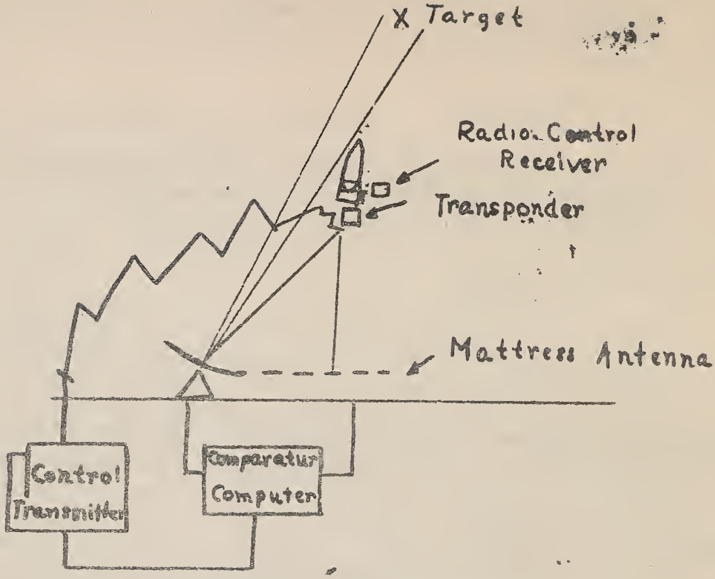
An IR photo electric (see separate report) proximity fuze developed by a Mr. Peucher who is now at Kochel. It transmits a scanned light beam and receives the reflection. Can operate on visual or infra-red.

ELAC.

The Electro-Akustic Company had under development optical, acoustic and infra-red homing systems. This company was first at Kiel, later moved to Namslau, Schlesien. When the Russians approached, the personnel moved out and left the laboratories intact. Dr. Kutscher and Dr. Hecht, two of the key personnel, are now probably near Bleicherode.

Rheinland.

This was the name for the ground equipment of a radar-radio control system for Wasserfall under development by Telefunken. The operating frequency was around 500 mc.



The radar was used solely for tracking the target and actuating a transponder aboard the missile. A separate receiving mattress would then track the rocket by the transponded signal. The bearing angles of the two antennas would then be compared and an appropriate control signal sent to the rocket to bring it back into the beam. It was developed for line-of-sight operation but some thought was given to collision course operation.

Zirkle.

A system similar to Rheinland but operating at 23 cm.

------ 0 ------

Von Braun stated that all homing systems under development for Wasserfall utilized computed collision courses. His feeling was that chosen courses for supersonic speeds were not practical. The only exception was line-of-sight courses as obtained with radar beams.

[illegible] von [illegible]

By: [illegible] Hull at Garmisch, 5 June 1945.

A pressure system of feeding reactants was chosen for Wasserfall (C-2) because it is more economical of space and weight than a pump system would be for this size of rocket. The size for which a turbine-pump system begins to be desireable depends on several factors such as speed, type, duration of burning but probably occurs in the 10-15 T (metric) thrust range.

Several types of pressurizing have been tried experimentally such as:

(a) Pressurizing with a slow burning powder. This is hard to control since burning speed rises with pressure. Valving excess powder gas to the outside hasbeen tried. In any case some sort of pressure regulating valve must be used.

(b) Pressurizing by combining the main rocket reactants. This device is considered most promising. A small air bottle is used to start the process which thencontinues with proper regulations. When using the Visol-Salbei combination water vapor is deposited in the Salbei Tank which promotes corrosion. This is no great trouble in military shots but in test rockets where several runs may be required difficulties arise. Three to four runs may be the life limit of the acid tank under these conditions.

Another reason for the use of pressurized tanks for reasonably large rockets is that the stoutly constructed tanks make excellent airframes, particularly in rockets requiring large radical accelerations with consequent high stresses. For instance, C-2 is calculated for radical accelerations of 12 g with a safety factor of 1.3. During certain parts of its trajectory thisrocket can perform turns ofthis value.

About half of the explosive charge carried by C-2 is in a form similar to prima cord distributed in tubes through out the missile in order to break it up so that it will not cause damage when falling on home territory. This is one of the reasons for the central tubes thru the reactant tanks since they can be more easily broken up from the center. Another excuse for central tubes is that welding stresses are smaller with this construction than with tubes near the edges.

It is possible that the flexible reactant outlet pipes may be hung up on these tubes but the usual course followed by C-2 would not permit this. It was agreed that a circling airplane would probably cause embarassment.

A Roman candle type of powder (Bengal fire) is burned in the air pipe on the high pressure side of the regulator valve in order to reduce the amount of air required. The powder is confined behind gauze to prevent ash from entering the air stream. Forty five second burning has been obtained. A 30% saving is made in the air flask size by means of this device.

The two main reactant valves are mechanically connected to give a time delay to the Visol so that Salbei will have time to enter the cooling jacket, pass thru it and the nozzles, and be present in the combustion chamber before Visol arrives in the chamber. In this way explosions are avoided since there is always sufficient O_2 carrier present to burn with a minimum time delay, the Visol as it arrives. Visol is admitted through its valve about 1/5 sec after the Salbei valve is opened. Visol can be admitted first but this arrangement does not start combustion as smoothly as in the previous arrangement. The two reactants must not appear in the combustion chamber simultaneously since a small ignition delay would cause an explosion.

In the nozzle design the jets are so arranged that flame is kept away from the combustion chamber walls. In addition two rows of holes, one just above the throat and one near the max. chamber diameter admit 3-5% of the total flow of Salbei directly into the combustion chamber for wall cooling. By these means wall temperatures are kept down to 300 to 400°C. Choosing the position of the auxiliary cooling jets is always an experimental procedure. Apparantly the burning time is too short to have the oxidizing atmosphere at the chamber walls make any difference in oxidation.

German 1263 or 1265 steel (Mn 2-3%) is used for the combustion chamber. A steel is wanted which can be formed and welded easily and which will have high strength at 400°C. Welding is difficult. In the beginning it was necessary to anneal the completed chambers but as a progressive, symmetrical welding technique was worked out, the anneal was unnecessary.

Heat transfer at the throat is estimated to be 10 times that at the max. dia. of the combustion pot or at the exit.

The cooling jacket space is 5-6 mm wide and constant. This spacing is maintained by placing wires of that dia. along the elements of the geometrical body.

Two pipes lead Salbei down to the distribution bulge at the venturi exit. One had been used sucessfully in test.

The latest nozzle disk is reported to be cast, then rolled and/or machined to shape. Fig 1 shows a radial cross-section of the nozzle and Fig 2 a view of one quarter of the disk as viewed from the combustion chamber. The disk is cast with the radical and circumferential passages for Salbei cored in. The Salbei slots are closed up by rolling and then machined out to about 0.8 mm wide or rolled up to a spacer. Visol slots are end milled to the same dimension thru the casting. There are about 8 rings for Salbei and 7 partial rings for Visol.

Two opposing schools exist in nozzle design, parallel and inclined. It is cheaper to build parallel nozzles and the turbulence in the combustion chamber soon mixes the jets.

Stoichiometric proportions are not used as higher exit velocities and lower max. temperatures can be obtained with other proportions. The expression for gas exit velocity follows.

$$c = \sqrt{2g\frac{k}{k+1}\left[1-\frac{P_c}{P_e}\right]^{\frac{k}{k-1}}} \cdot \sqrt{RT} \qquad (1)$$

Where

c= exit velocity

g= gravity constant

k= gas specific heat ratio

Pc= combustion chamber pressure

Pe= exit pressure

R= gas constant = $\frac{848}{\mu}$

μ = molecular weight of exhaust gases

T = combustion chamber temperature.

Since the first radical is practically constant, exit velocity depends on R and T. Two values are wanted which when multiplied will give the largest number. This max. value does not occur at stoichiometric proportions since under these conditions the fuel will be burned to CO_2 with a μ of 44. If more Salbei or Visol is added there will be relatively more O_2 (μ =32) or CO (μ =28) in the exhaust gases. Altho T will be lower under these conditions R will be considerably higher giving a greater value to RT. Fig 3 shows this relationship for Wasserfall and Fig 4 for A-4. Note that C-2 uses an excess of oxidizer and A-4 an excess of fuel, the excess in each case being the coolant.

The exit velocity of the C-2 venturi is 1800 m/sec over about 90% of the exit diam.

In the following equation written for gravity free vacuum , will be found the reason for desiring high specific gravity in rocket reactants,

$$m\,dv = c\,dm \qquad (2)$$

$$dv = \frac{c\,dm}{m} \qquad (3)$$

$$v = c\int\frac{dm}{m} = c \ln \frac{Mo}{m_1} \qquad (4)$$

where

M = rocket mass
M_t = " " at start
M_η = " " empty
v = rocket velocity
c = gas exit velocity

Maximum velocity will be obtained when the ratio of initial mass to final mass is greatest or when reactant weight to final weight is heighest. This state can be approached by putting the greatest possible weight of reactants into light Tanks. Tanks for high specific gravity reactants will be ~~higher~~ lighter for a given weight of reactants, sincethey will be smaller.

In tests of A-4 a good burner will produce a visible gas stream 12 - 15 m long with no side flame. The color is mainly yellow from salts and Alumium oxide. The sodium D line shows principally in analysis. About 10 sets of Mach's waves can be seen in such a jet. These lines are straight, showing that the gas velocity is constant across the jet, and maintain about a constant angle along the jet since as the jet velocity reduces the gas cools lowering the acoustic velocity thereby maintaining a constant Mach angle.

There would be parts for several complete C - 2's in the vicinity of Bleicherode or in transit thereto.

von Braun has several photographs of Prufstand No. 1 at Peenemünde which should be reproduced. Perhaps other photographs could be found through interrogation.

The above report represents what was reported to the writer, not his own views.

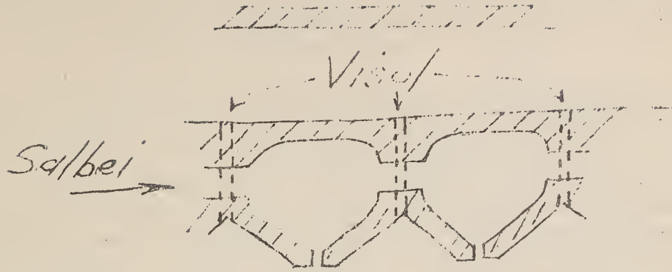


Fig. 1.

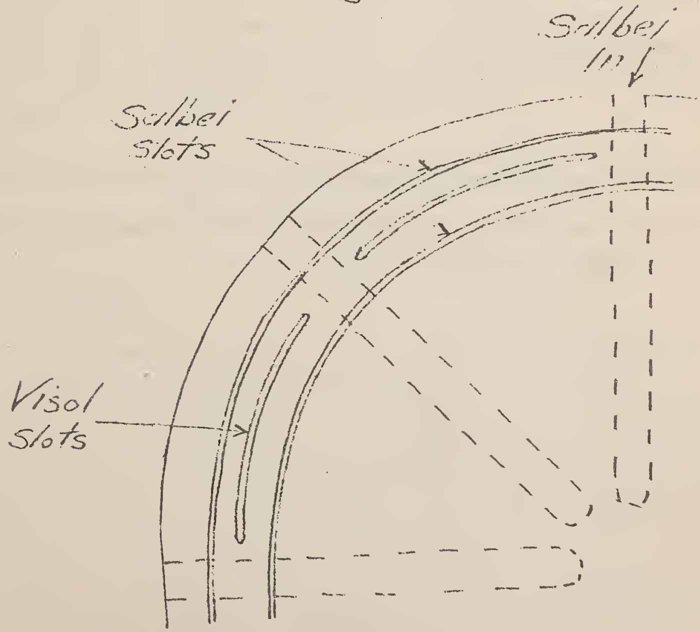
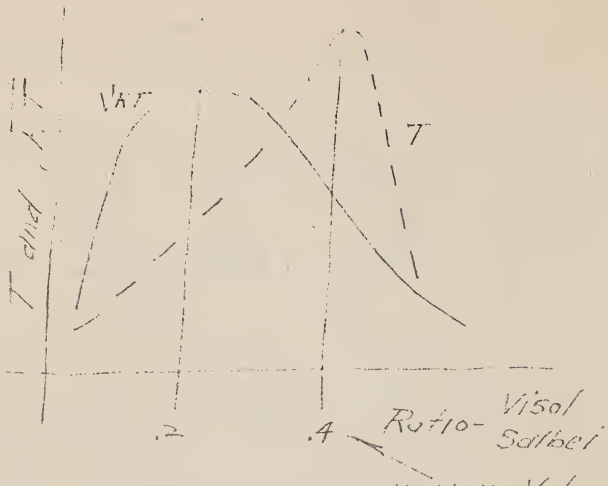
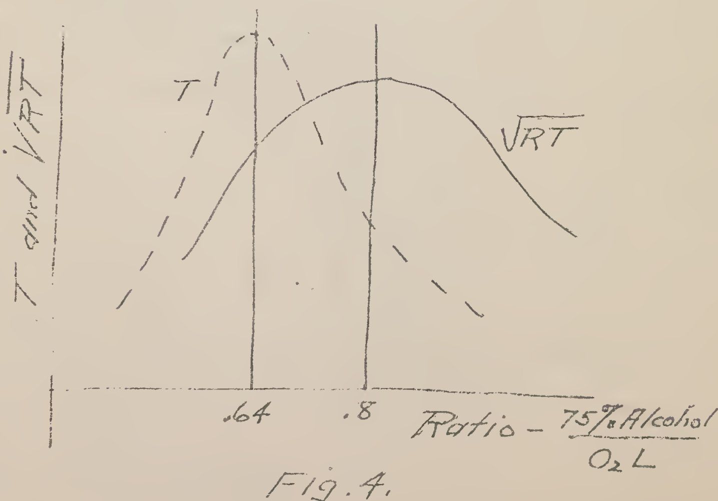


Fig. 2.



T and √RT
√RT
T
.2
.4
Ratio - Visol / Salbei
Approx. Value

Fig. 3.



T and √RT
T
√RT
.64
.8
Ratio - 75% Alcohol / O₂ L

Fig. 4.

Interrogation of Von Braun, Dannenberg and Klausz, by E. H. Hull at Garmisch-Partenkirchen on 7 June 1945.

The purpose of this interrogation was to correct mis-statements which were made on 6 June 1945, concerning regulator valve design and to amplify Von Brauns statements of 5 June 1945 regarding pressurization of reactant tanks by means of Salbei-Visol combustion pot.

Fig. 1 shows the regulator valve as redrawn. When no pressure is applied the spring forces the valve spindle down against the stop. As pressure is applied the valve spindle is raised since the spindle area above the high pressure chamber is greater than the corresponding area below. N_2 flows past the first throttling point on the lower valve spindle then past lower two which are set more open since they act as valve surge dampers rather than throttles. Pressure is taken from the low pressure side up to the bellows at the top of the assembly. Pressure inside the bellows is the determining factor in the position of the valve at any instant. It is claimed that, for a given flow rate of regulated gas, pressure can be kept constant at 27 atu with an inlet pressure running from 250 down to 30 atu. If the flow rate changes then the spring adjustment must be changed to maintain the same pressure since the valve requires a different opening for a different flow rate and the gas forces on the lower portion of the valve spindle will vary with flow rate.

The upper portion of the valve spindle is grooved to form a labyrinth packing to prevent excess high pressure gas leakage. A tight packing in this place would cause friction.

Normal steel is used in the valve construction with the exception of the bellows which is bronze.

Fig. 2 indicates the force balance in this valve for high and low inlet pressures. Zero displacement of the spindle is taken when the spindle is as far down as it will go. At this point there is a definite downward spring force on the stop. When high pressure air is admitted the net force raising the spindle reduces with increasing spindle deflection. Equilibrium is reached when the net upward air force in the spindle equals the downward spring pressure. This equilibrium point will occur at different spindle displacements for different inlet pressures as indicated in Fig. 2.

Fig. 3 indicates an auxiliary combustion system for pressurization of the main tanks. A small nitrogen flask delivers regulated pressure to small reactant tanks which in turn supply the combustion chamber. Gas from the combustion is carried directly to the main reactant tanks. This system should be self regulating to a certain extent.

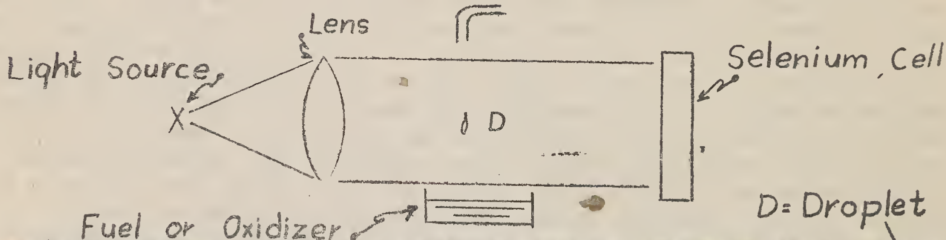
Such a device has been studied experimentally but never flown.

Garmisch-Partenkirchen
May 20, 1945

I n t e r v i e w with Dipl.ing. Magnus von B r a u n

Interrogator: Dr. F. Zwicky

Tested orginally in the laboratory the question of spontaneous ignition time of mixed fuels. Thinks that smallest they had was approximately 1/1000 second.



Tried various amines. Price considerations eliminated the practical use of many of these substances. Tried about 1300 combinations. Ignition time was measured with the scetched arrangements (darkening of the field when the dropplet passes and brightening from the flame) Sine October 1943 he worked as technical and liaison man for his brother (Previously he worked with Prof. Hans Fischer in Munich T.H. on synthesis of chlorophyls, hemine, gall bladder dyes etc. Had some of the syntheses almost in hand).

67890

(A-9,A-10)

INTERROGATION OF PROF W. von Braun on LONG- DISTANCE ROCKET, XXXXX

BY: E.H. Hull, W.Hausz,R.W.Porter on 7 June 1945, Partenkirchen.

Prof. van Brau was questioned at length on the basis of his statement in " Survey of Development of Liquid Rockets in Germany and their Future Prospects" that the A 9 rocket combined with the A 10 boost would have a range of 5000Km.

The A 9 rocket is essentially an A 4 with about seven square meters of wing surface added. Acting alone it climbs to about 29 kilometers at which height it has a velocity ofapproximately 1300m/sec. It then glides to a range of 600 Km, and an altitude of 5 Km, where upon it dives on the target, if a military weapon, or engages in some sort of landing procedure if a cargo carrier. The A 10 rocket was to have been a booster for the A 9 having 200 tons thrust for 50 - 60 seconds. With this boost the A 9 would be"launched" at 1200 m/sec. and would continue until it reached an altitude of 55 Km and a velocity of 2800 m/sec. It then begins a long gliding trajectory which carries it to a range of 5000 Km. Prof von Braun insisted that this range value had been substantiated by accurate trajectory calculations. He pointed out that the centrifugal force, due to the curvature of the earth was an important factor as well as the changing air devaities, the gradually changing velocity of the projectile etc., and that it was important to select the best trajectory in order to obtain or attain the maximum range.

He showed by means of energy relations that for a flat earth the range would be approximately proportional to the initial velocity squared. The difference between this result and his claim he believed to be due to curvature of the earth. It seems more likely to the writer that this difference if it actually does exist is more likely due to the relation in drag coefficient at high Mach numbers. (See Appendix)

Prof von Braun was not able to remember any numerical values for the ratio CL /CO but said they could be found for A 9 in reports at Kochel.

For future work, von Braun was interested in supersonic Lorin motors (ramjets) because of their high efficiency.

He said he had often talked with Dr. Hermann about the diffuser for such a motor and that tests had been made in the wind tunnel. These tests were closely related to the supersonic diffuser used for pressure recovery in the wind tunnel itself. Considerable success was had in shaping the diffuser to reduce the energy loss from the pressure waves. Pressure recovery of as much as three or four to one had been obtained. In his example, Prof von Braun indicated a velocity of 600 m/sec in the combustion chamber. Asked if he thought combustion couldbe maintained at this speed he said hethought it could. For example, some combustion still took place in the A 4 jet where velocities of over 1000 m/sec existed. No combustion chambers for Lorin motors have ever been tested by von Braun or his staff.

Incidental Information:
Temperatures in thejet were measured by a standard optical method in which a lamp with a variable density filter is placed on one side of the jet anda spectroscope is placed on the other. A trace of sodium salts is added to one of the reactants(if not already present) so that a strong sodium line exists in the luminosity of the flame. By varying the density of the filter until the line disappears in the spectroscope the temperature can be determined according to a previous calibration. Velocities are then determined from the visible pressure waves in the jet. Pressures are rarely ever measured in the interior of the jet; surface pressures are sufficiently accurate for all purposes. Gas samples are taken with a water cooled tube which is inserted directly into the flame.

Prof von Braun thinks that tetranitromethane would make a very good oxygen carrier. For example he believes that Wasserfall could be loaded with tetranitromethane instead ofSalbei and fired without any change. Advantages, easier handling, higher sp.gr., no low temperature, reasonably good spec. thrust.

R.W. Porter.

APPENDIX: Comparison of Range for A 9 alone with that for A 9-A 10 Combination.

Assume rocket is delivered at a height above the target H, with a velocity, Vo. If it glides at an angle, θ, its equations of motion (neglecting the earths curvature) will be

$$\text{Drag} = m\frac{dv}{dt} + m\,g\sin\theta \qquad (1)$$

$$\text{Lift} = m\,g\cos\theta \qquad (2)$$

$$\text{or } \frac{cd}{cl} = \frac{1}{g}\frac{dv}{dt} + \tan\theta \qquad (3)$$

[dividing (1) by (2) and assuming $\cos\theta = 1$]

By definition,

$$\tan\theta = \frac{H}{R} \quad \text{(where R is the range of the target)} \qquad (4)$$

Assuming a constant decelleration,

$$\frac{dv}{dt} = \frac{Vo}{T} \quad \text{(where T is the time of flight)} \qquad (5)$$

and

$$R = 1/2\ VoT \qquad (6)$$

Substituting (4), (5) & (6) in (3).

$$\frac{cd}{cl} = \frac{1}{R}\left(\frac{Vo^2}{2g} + H\right) \qquad (7)$$

or

$$R = \frac{cl}{cd}\left(\frac{Vo^2}{2g} + H\right) \qquad (8)$$

Substituting the values for the A 9 alone in (7), R= 600 km, Vo= 1.3 Km/sec, H= 24Km,

$$\frac{cd}{cl} = \frac{1}{600}\left(\frac{1.69}{2x.01} + 24\right) = \frac{1}{600} \times 108 = \frac{1}{6} \text{ approx.} \qquad (9)$$

Using this value, and the data for theA 9 - A 10 combination, Vo = 28 Km/sec, H= 55 Km

$$R = 6 \left(\frac{7.84}{.02} + 55\right) = 6 \times 447 = 2680 \text{ Km.} \qquad (10)$$

The centrifugal forċe on the missile as it follows a curved path of approx. 6,4000,000 meters radius at a velocity of 2800 m/sec ~~mtx~~ will be

$$\frac{V^2}{R} = \frac{7.84 \times 10^6}{6.4 \times 10^6} = 1.3 \text{ m/sec or } .13\text{xg}$$

In the case of a missile at 1.3 Km/sec the fprce ~~mt~~ would be less than .03g, consequently over a part of the path there would be an advantage of 10% in the C_2/CD ratio in the case of the higher speed missile because of the centrifigal force.

A much more important factor, however is probably the fact that at speeds in excess of M=1 the draz coefficient decreases with increasing speeds. Hence an increase of nearly 2:1 as would be required in order to obtain 5000 Km range would not be impossible.

Discussion with Prof. Dr. Von Braun.   15 May 1945

Present: Lt. Col. G.J. Gollin and F/Lt. H.M. Stokes.

After introducing Lt. Col. Gollin to Prof. v. Braun as a "rocketeer", F/Lt. Stokes asked the Professor to amplify and clarify certain points in the schedule of the "A" weapon development which the Professor had given verbally the previous day. This account had not been in chronological order but during this interview, v. Braun recapitulated the work in the order in which it had been carried out and at the same time handed over a memorandum on the development (past and possible future) given as Appendix I. It was suggested on the previous day that such a memorandum might be prepared. Using this memorandum and the discussions as a basis the chart in Appendix II has been prepared.

A general discussion followed on Thrust Motors during which the following points were raised.

(a) Query.

During a visit to B.M.W. at Muenchen Allach Dr. Hemesath mentioned characteristics of rockets 548 and 558 as being 1000 Kilo/tonne sec. and 10,000 Kilo/tonne sec. What was the usual German method of specifying thrust, and could v. Braun explain the above figures?

Answer.

He was not familiar with the numbers 548 and 558. (We explained that they were nitric acid tonka AA units.) The specific thrust is always given as grammes/Kilo.sec. Thus, for A 4, the thrust is 4,75 grammes/Kilo.sec., equivalent to a velocity of 2070 metres/sec.

v. Braun could not understand the figures given by Dr. Hemesath, and suggested that following the procedure normally used with "powder" rockets, the figures might represent the area of the thrust time curve. (Fig. 1)

(b) It was mentioned that in England we had run a thrust motor on 1:4:1 Oxygen: Alcohol. v. Braun asked why this was, seeing that they used 1:0,85 (1,175:1) on the A 4, the stoichiometric ratio being 1:0,64 (1:56:1. Col. Gollin queried this figure, saying that for EtOH the stoichiometric ratio was 2,09:1, but was reminded that their fuel contained 75% alcohol & 25% water.

v. Braun drew two curves v RT against fuel: oxygen ratio showing the peak at the stoichiometric ratio at 0,64 for oxygen and neat EtOH, while the second curve had the peak at 0,85 for O_2 and 75% EtOH plus 25% water. Fig II.

Von Braun described the thrust as C,

where

$$C = \sqrt{2g\frac{X}{X+1}\left(1-\left(\frac{p_1}{p_2}\right)\right)^{\frac{X-1}{X}}} \times \sqrt{RT} \quad G!!!$$

where R = $\frac{848}{\mu}$ $\left(= \frac{1,985 \times 428}{mol.-wt.}\right)$.

(c Query. Where was the flame front?

Answer.

Right at the burner caps and possibly almost inside. v. Braun agreed that for cooling it was desirable to keep the flame away from burner end, but pointed out that in doing so a loss of efficiency resulted. The "carburetor" burner cups were his essential patent and formed the basis of all the "A" series of weapons.

(d Query.

Had they done better than 4,75 grammes/Kilo.sec?

Answer.

On the test bed they could do 4,5 gm/Kilo.sec. (S.I.= 222 but for operational purposes 4,75 was adequate.

(e Query.

Had they ever tried using gasoline instead of alcohol?

Answer.

Yes, in 1935, but the combustion was poor - everybody in the test stand got dirty with carbon, but the most important point was that petrol was proved to be a very bad coolant, tending to gas and give uneven cooling.

(f The use of graphite.

The graphite was the same as used for electrodes. As the blades in the gases were employed to give stability until a sufficient velocity was reached to enable the outer blades to assume control, it had been found that oak blades would last long enough.

(g Surface cooling.

This was not necessary until they employed high initial temperatures. Even then only the hottest surfaces had surface cooling. They had tried venturis of various metals, including molybdenum.

(h Query.

In A 1 & A 2 the fluids were gas expelled, how did he like pushing out liquid O_2 with nitrogen?

Answer.

Very difficult and expensive with gas. In order to avoid condensation you must prevent the N_2 from bubbling through the liquid O_2. This had been achieved by introducing the N_2 through two opposed jets, Fig. 3. This prevented the nitrogen jet from impinging on the liquid O_2 surface. Col. Gollin mentioned pistons, but it was pointed out that in these early models the fluid containers were spherical, and hence a piston was impossible. They had, however, used small wooden balls to cover the oxygen surface. When the surface was near the top of the sphere or the bottom, the balls bunched together, but at the "equator" they spread evenly over the surface exposed. These balls did not appear to be generally used. (Fig. 3 .

(i Combustion chamber pressure in A 4.

Only 15 atmospheres was used in the operational A 4 combustion chamber. v. Braun drew a curve showing that he was aware that with higher pressure drops better "impulses C" could be obtained (Fig. 4 .

(j Query.

Why did he not insulate the liquid oxygen tank?

Answer.

Latterly at the request of the troops it was tried because while they normally fired as soon as the liquid O_2 was in the machine and hence avoided evaporation loss, owing to air raids sometimes the machine had to stand filled for a period. Experience showed that the lagging increased the evaporation loss due to the heat capacity of the lagging.

(k Did they fill by the O_2 pressure or by pump?

Answer.

By pump in 12 minutes. O_2 pressure transfer was avoided because

(1 The tanks on the waggon had to be made stronger to stand the pressure.

(2 On releasing the pressure a cloud of vapour clearly visible was released, which was objectionable to the troops.

(3 Pressure transfer was wasteful of O_2 as at the end one released a considerable quantity of O_2 vapour at high pressure (Fig. 5 .

(l Query.

With reference to air bursts, did he think the skin temperature reached the stagnation temperature?

Answer.

No, because (1 the film temperature was only the main air temperature x factor $X \frac{v^2}{2000}$ °C This factor being 1 for a plate at right angles to the air stream and 0,86 for a surface parallel to the air stream. (Fig. 6 .
Having got the film temperature, one could calculate the equilibrium metal surface temperature.

Metallurgical examination of the metal after explosion would give an exaggerated figure because after the explosion the plate would be heated on both sides: also the velocity after the explosion would be higher than the projectile velocity. They had measured by radar the skin temperature as the projectile fell through the atmosphere and had checked that it did not exceed 650°C.
v. Braun owed his life to the fact that a rocket which was falling back on the launching site burst in the air.

(m Query.

The overall density of the loaded rocket was very low about 1/3rd water. Had they improved this by using the skin as tanks?

Answer.

This was done for Wasserfall, but for A 4 larger tanks could be used. The use of the skin as tank presented difficulties due to the high external excess pressure when falling with empty tanks. v. Braun drew a curve showing the external pressure distribution over the projectile.

The high pressure around the nose could through a leak in the skin build up a pressure on the leading surface of the internal tanks causing a resultant thrust to the rear which might cause the tank to move see sketch, Fig. 7.

(n Query.

On A 4 the ratio of T Stoff tank capacity to Z Stoff tank capacity was 25:2 i.e. 12,5:1 by volume, on the other hand, on G.A.A. T.O.R. and H.S. 293 the ratio was 25:1.

Answer.

On A 4 it is essential that the steam temperature to the turbine be kept constant. The concentration of the H_2O_2 may vary but this can be compensated by altering the calcium permanganate solution by putting in more or less water as required.

(o The "A" weapons will have their range extended by the addition of wings (fixed which enable the rocket to do a long glide at conclusion of the power stroke. They have decided that the density of the atmosphere at heights is such that rockets would not glide satisfactorily from over 30 Km in height (i.e. about 100,000 ft. The trajectory of the power stroke of these rocket launched projectiles would be in two parts and bent over much lower than the natural trajectory of A 4 (See sketch 8 .

The combined glider A 9 plus rocket boost A 10 is illustrated (sketch 9 A 10 would operate at 200 tonnes for 50 seconds, and the A 9 at 25 tonnes for 68 seconds. Velocity at end of launch 1200 m/sec. and at end of power stroke 2800 m/sec. It follows that if A 9 is used alone, its velocity at the end of the power stroke would be 1600 m/sec.

(p Query.

Did the Professor think that the gases being in equilibrium at high temperature in the combustion chamber recombined during the expansion?

Answer.

They had sampled the gases in the combustion chamber by Orsat through highly cooled tubes. They "froze" the gas mixture. By this means they checked that the gas in the combustion chamber at high temperature reached equilibrium state.

From time to time v. Braun tried to explain in English, in which language he was fairly lucid. He was very cooperative and seemed very pleased to discuss his past technical difficulties with a worker in the same field. It was agreed to continue the conversation at a later date.

SURVEY OF DEVELOPMENT OF LIQUID ROCKETS IN GERMANY AND THEIR FUTURE PROSPECTS

By Prof. W. von Braun

1. We consider the A-4 stratospheric rocket developed by us (known to the public as V-2) as an intermediate solution conditioned by this war, a solution which still has certain inherent comings, and which compares with the future possibilities of the art rought in the same way as a bomber plane of the last war compares with a modern bomber or large passenger plane. We are convinced that a complete mastery of the art of rockets will change conditions in the world in much the same way as did the mastery of aeronautic and that this change will apply both to the civilian and the military aspects of their use. We know on the other hand from our past experience that a complete mastery of the art is only possible if large sums of money are expended on its development and that setbacks and sacrifices will occur, such as was the case in the development of aircraft.

2. A few private groups of inventors started serious work on liquid rocket development in Germany in the years 1929-1930. One of these groups, called "Rocket Flying Field Berlin", located at Berlin-Reinickendorf, had Prof. Dr. von Braun as a student among its members. Simple fundamental tests with rocket combustion chambers were carried out there, and small uncontrolled liquid rockets were fired, which reached heights up to 1000 meters, and landed by means of a parachute. At the end of 1932, the work of these groups was slowed down by lack of cash, but the Army Weapons Department was interested in carrying on the work, and took over the services first of Prof. von Braun, and later of most of the other engineers. This special division of the Army Weapons Department was put under the direction of Dr. Ing. H.C. DORNBERGER, and the first rockets developed by them were designed solely for experimental purposes, and were of no military value. In 1934, liquid rockets of the "A-2" type were successfully tried out. They had a thrust of 300 kg., were directly stabilized by means of a large gyro, and reached a height of approximately 2000 meters. In 1938, the first trials were carried out with liquid rockets of the "A-3" and "A-5" types, which were fitted with an automatic control system and rudders in the gas stream. These rockets

reached a height of 12 km. when fired vertically, and had a range of 18 km. when fired at an angle. They could land in both cases by means of parachute, and be used again.

3. In view of the successful results achieved with liquid rockets, it was decided in 1936 to begin with the construction of a large experimental establishment for rocket development at Peenemunde on the Baltic. It was already recognized at that time that the development of rockets showed great promise in the field of aeronautics as well as in that of artillery, and it was therefore decided to build two separate establishments at Peenemunde, one for the Army and one for the Air Force, which are two distinct branches of the Wehrmacht in Germany. At Peenemunde-Ost, comprehensive test beds and work-shop facilities were set up for the construction and testing of rocket drives and controls, whilst at Peenemunde-West an airfield was built for testing rocket aircraft, and pilotless rocket propelled aircraft, as well as auxiliary drives for standard aircraft, such as rocket assisted take-off devices. The cost of construction of the complete installation at Peenemunde totalled approximately 300,000,000 Marks after completion. This close proximity of the rocket development work to the aeronautical developments is one of the principal reasons for the success of the work undertaken at Peenemunde.

4. The following considerations were decisive in the choice of Peenemunde, and these considerations will always be important when choosing a site for rocket development work:

a) Secluded position, far away from large towns (Safety during launching, nuisance caused by noise of large test beds).

b) Favorable weather conditions (during firing and flight trials of rocket and rocket aircraft, blue skies are always desirable).

c) Reasonably satisfactory communications. The development work necessitates constant close contact between development engineers and certain branches of industry.

5. The successful experimental rocket "A-5", previously mentioned, had a thrust of 1500 kg. lasting 45 seconds. Based on the results obtained with the rocket,

the order was given to develop a long distance rocket with a range of 250 km., as high an accuracy as possible, and a warhead weighing 1000 kg. This rocket, known as "A-4" was first launched successfully in October 1942. The "A-4" has a thrust of 25 tons, for combustion period of 68 seconds max. It is fired vertically from a firing table, without guides of any sort, as was the case with all the previous rockets. The speering of the rocket to an inclined position is effected by means of a "programme" apparatus. The lateral direction is determined by the exact setting of a turntable on the firing table. The exact range is determined by shutting off the propulsion unit upon reaching a previously calculated speed.

6. The development of the "A-4" required a great number of preliminary scientific investigations, the most important of which are briefly outlined below:

a) Wind tunnel tests at all ranges of air speeds between 0 and 1500 meters per second. During these tests, such factors as the stability of the rocket, the distribution of the air pressure, the working of the rudders and several more were investigated, apart from the drag measurements, both with and without exhaust gas stream. Both the supersonic wind tunnel and the measuring methods had to be developed over a period of years of hard work.

b) Test bed investigations on the combustionchamber of the rocket, and on the complete propulsion unit. This too necessitated the development of appropriate test beds and measuring methods.

c) Investigations connected with the steering of the rocket at all ranges of airspeeds covered by the rocket. For this purpose, a special technique of models, reproducing the attitude of the rocket in flight, was developed.

d) Development of measuring methods for plotting the complete flight path of the rocket.

e) Investigation connected with the influence of the exhaust gas stream on the wireless communication between rocket and ground, etc.

7. In view of the increasing strength in the numbers of light aircraft in England, and the resulting increased

losses of bombers operating against England, orders were given at the end of 1942 to produce the "A-4" rocket in quantities. The accuracy of aim was still unsatisfactory, and limited the use of the rocket to large area targets, foremost of which was London. Nevertheless, some 60 to 65,000 drawing modifications were required before the first experimental A-4 rocket became a real serious production job. This indicates how many absolutely new problems arose during the trials of the A-4, which was subjected to hitherto unknown physical conditions.

8. Meanwhile, the development side was attempting to improve the accuracy of aim of the rocket. To this end, radio guide beam devices were developed to improve the lateral direction, and improved propulsion unit cut-off devices to reduce the dispersion in range. These improvements, however, were incorporated operationally on a small scale only, and were in use chiefly in the attack on the harbour of Antwerp. The original objective of further development was to produce long distance rockets of greater range. It should be noted here that the maximum ranges up to 480 km. were achieved thanks to certain improvements, which, however, never came into operational use. Certain A-4 rockets were used to carry out vertical trajectory trails, and a maximum ceiling of 172 km. was reached during these trials.

9. It was planned in the Spring of 1945 to give vertically from an island situated near Peenemunde a few A-4 rockets equipped with special instruments for research into the top layer of the atmosphere. The measuring instruments were set in a watertight container capable of floating, which was to have descended by parachute. This project, all preparations for which were completed, could not be carried out on account of military events. It could be done in a short time, however, with some of the A-4 rockets still at hand.

10. The problem of increasing the range of the A-4 after completion of the A-4 development programme could only be carried on at a greatly reduced rate, as the development of a guided anti-aircraft rocket was given first priority and absorbed most of the personnel, in consequence of the increasing air superiority of the Allies. A rocket for this purpose was developed at Peenemunde, bearing the code name "Wasserfall". This rocket was also propelled by liquid fuel and could be guided by radio from the ground on to flying targets. Various successful tests were carried

out, but serious production of the weapon was not achieved.

11. A further development of the A-4 long distance rocket is the "A-9", on which work was done as far as the priority work on "Wasserfall" would allow. The propulsion unit was the same as for A-4. The A-9 rocket, however, had wings, which enabled it to glide through the stratosphere. This enabled the flight path to be increased to such an extent that the range of the A-9 was nearly double that of the A-4, v.e. approx. 600 km., notwithstanding the fact that the fuel consumption of the A-9 was no greater than that of the A-4, development could not be completed on account of the end of the war. Special control devices would have given the A-9 at least the same accuracy as the A-4. It was proposed that the weapon should go into a vertical dive at the end of the glide, similar to that of the V-1.

12. As a further development, it was intended to design the A-9 winged rocket to carry a crew. For that purpose, the rocket was to be equipped with a retracting undercarriage, a pressurized cabin for the pilot, manually operated steering gear for use when landing, and special aerodynamic aids to landing. The landing speed of this piloted A-9 rocket would have been as low as 160 km per hour, as it would have contained very little fuel on landing, and would consequently have been light. This piloted A-9 rocket would cover a distance of 600 km. in approx. 17 minutes.

13. The range of the A-9, both in the piloted and the pilotless versions, could be increased considerably if the propulsion unit were switched on only after the rocket had obtained a certain initial velocity. There were two possible ways of achieving this end:

a) Use of a long catapult with only a slight gradient, which would have given the rocket an initial velocity of approx. 350 m/sec. There was experience of this type of catapult to hand at Peenemunde, as such a catapult developed by an industrial firm for launching the V-1, was tried out at Peenemunde. Experience showed that catapults could be built for launching at supersonic speed. These high speeds are essential for rockets such as A-9, because the rocket is completely filled with fuel at the start and would not fly if it left the catapult at lower speeds.

b) Development of a large assisted take-off rocket of 200 tons thrust, on which the A-9 rocket would be mounted, and which would give the latter an initial velocity of 1200 meters per second. After the assisted take-off rocket has exhausted its fuel, the A-9 would become separated from it, and its own propulsion unit would be switched on. The maximum speed of the A-9 at the end of its power drive under these conditions would be approx. 2800 meters per second, which would mean that this combination could give the A-9 a range of approx. 5000 km., both in the piloted and the pilotless versions. The large assisted take-off rocket, called "A-10", was to be equipped with air brakes and a special parachute, which would have enabled it to be used again after alighting on water.

c) It was proposed to launch the A-9/A-10 combination vertically, thus obviating the necessity of erecting large ground launching devices.

14. In the more distant future, the development of liquid rockets offer in our opinion the following possibilities, some of which are of tremendous significance:

a) Development of long range commercial planes and long range bombers for ultra high speeds. The flight duration of a fast rocket aircraft going from Europe to America would be approx. 40 minutes. It would even be possible to build very long range bombers, which would turn round at supersonic speeds in a very wide curve after having released their bombs, and return in a glide to land at their point of departure. The high speed of such aircraft would make defence against them ineffective with present day means.

b. Construction of multi-stage piloted rockets, which would reach a maximum speed of over 7500 meters per second outside the earth's atmosphere. At such speeds, the rocket would not return to earth, as gravity and centrifugal force would balance each other out. In such a case, the rocket would fly along a gravitational trajectory, without any power, around the earth in the same way as the moon. According to the difference of the trajectory from the earth, the rocket could complete one circuit around the earth in any time between 1½ hours and several days. The whole of the earth's surface could be continuously observed from such a rocket. The crew could be equipped with very powerful telescopes, and be able to observe even small objects such as ships, icebergs, troop movements, constructional work, etc. They could also carry out physical and astronomical research on problems which could only be tackled at that altitude, due to the absence of the atmosphere. The importance of such an "observation platform" in the scientific, economic, and military spheres is obvious. When the crew of the rocket want to return to earth, all they need do is to reduce the speed of the rocket slightly, which can be done by rocket propulsion. The rocket then enters the upper layers of the atmosphere tangentically, and itsspeed is gradually reduced by friction. Finally, it can land like an ordinary aeroplane by means of wings and auxiliary gear. It would also be possible to relieve the crew and provision the "observation platform" by means of another rocket, which would climb up to the platform and pull up beside it.

c. Instead of having a rocket set up as an "observation platform" outside the earth, it would be possible later on to build a station specially for the purpose, and send the components up into the interstellar spaces by means of rockets, to be erectéd there. The erection should be easy, as the components would have no weight in the state of free gravitation. The work would be done by men who would float in space, wearing diver's suit, and who could move at will in space by means of small rocket propulsion units, the nozzles of which they would point in the required direction.

d. According to a proposal by the German Scientist, Prof. Oberth, an observation station of this type could be equipped with an enormous mirror, consisting of a huge net of steel wire onto which metal foils could be suspended. A mirror of this nature could have a diameter of many kilometers, and its component facets could be controlled by the station which would enable the heat and light of the sun to be concentrated on selected points of the earth's surface. This would enable large towns for instance, to get sunlight during the evening hours. The weather, too, can be influenced by systematic concentration of the sun's rays on to distant lakes and seas, and increasing their evaporation. The clouds thus formed could be driven to the required spot by influencing the centres of low and high pressure through radiation from other facets of the mirror. If the mirror is made large enough, and it could be of extremely light construction, it would even appear possible to generate deadly degrees of heat at certain spots of the earth's surface.

e) When the art of rockets is developed further, it will be possible to go to other planets, first of all to the moon. The scientific importance of such trips is obvious. In this connection, we see possibilities in the combination of the work done all over the world in connection with the harnessing of atomic energy together with the development of rockets, the consequence of which cannot yet be fully predicted.

15. To conclude, we think after what has been said above, that a well planned development of the art of rockets will have revolutionary consequences in the scientific and military spheres, as in that of civilization generally, much in the same way as the development of aviation has brought revolutionary changes in the last 50 years. A prophecy regarding the development of aviation, made in 1895, and covering the next 50 years, and corresponding to the actual facts, would have appeared at least as phantastic then as does the present forecast of the possibilities of rocket development. In the same way as the development of aviation was not the work of a single man, but became possible thanks to the combined experience of many thousands of specialists, who concentrated exclusively on this one branch of science for years, so the development of the art of rockets will require a systematic effort by all specialists who have gained experience on this subject.

Garmisch-Partenkirchen, May 22, 1945

I N T E R V I E W with Prof. W. von Braun.

Interrogation: Dr. F. Zwicky. C.I.O.S. 183.

Thinks that the development of the various jet devices was purely accidental and whichever rut (Rille) the people were in they followed as a limited objective. At Argus there was Dr. Gosslau (whom Prof. Braun knows) who was an influential person (Argus is airplane engine factory) Dr. Gosslau had large staff of collaborators whom Prof. Braun does not know.

On the test stand Prof. Braun has seen only one intermittant motor (30-20 Herz).

Schmidt (whom Braun knows) claimed that a fuel consumption of 0.6 gr/Kg x sec. could be obtained with gasoline as far as Braun remembers.

(Definition: Assembly line = Montagebank. These may be of the type "Taktstrasse", or "Fliessband" for small parts, and "Laufendes Band" for larger parts).

Does not know if the efforts to achieve greater range were tried on the basis of greater fuel economy or on the basis of building larger units and better design.

On aeroducts windtunnel experiments were made, but nothing was brought to a practical conclusion.

Heisenberg worked on the chain reaction problem for U_{235}. (In Berlin - Dahlem). (Braun saw Heisenberg in 1942 the last time)

Thinks that "Hyrol" as a monopropellant was never used in any practical device.

States that the intermittant duct motors, in spite of their importance were relatively neglected.

A4 Oxygen Vent Valve

It did never ice up because it did not get cold until filling began and then had a long vent pipe to atmosphere. As there was a pressure in the 02 tank during filling, no moisture could get in. The risk however was worse in wet weather. The vent valve was made to serve two functions, it could be held shut by N_2 but would also act as a relief valve opening and shutting to preserve a pressure of not more than two atmospheres. It did this after Brennschluss because they wanted to maintain a pressure in the tank because it was not strong enough to withstand an excess pressure from outside due to the dynamic head from the velocity.

He had been told that he was mad to try to use Rubber or Buna but he proved that the Buna stood up well to the low temperature.

TAIFUN

Asked about the empty weight and fuel carried, von Braun seemed very vague and said that the original specification called for a thrust of 900 kilo and an acceleration at start of 80g. They had obtained a thrust of 600 to 650 kilo and an acc. of 60g. He though the all up weight was 13 kilo and the acc. at start 35g and at all burnt 60g. When shown the Comb. Chamber Head, he did not recognize it and said that it did not represent an operational model but was probably made by the order of one of his assistants who had liberty to experiment. The ring did not go in the Comb. Chamber but transferred the thrust to the Projectile. He knew that Walther used targets but did not like them.

Discussing L $\star$ he agreed that he normally used 250 cms or 100" and agreed that the L $\star$ for TAIFUN was very small i.e. about 30". They accepted a low S.I. to get more room for the fuel tanks. Taifun probably only produces 160 S.I. Von Braun said that given correct mixing at the introduction of the fuels, the rest of the comb. chamber did not matter much.

A4 Accidents.

At Heidlarger, most of the failures were due to the Troops. He was there when due to a faulty electric connection, Brennschluss took place very early and the rocket quickly fell to earth. Most took the right direction but some failed to bend their traj. over and went straight up. The W.H. did not explode in such cases as it was not yet armed but it was likely to go off due to heat of the fire after half an hour on the ground.

The two bangs on correct impact were due to the Mach wave.

Magnus V. Braun, Diploma Engineer.

On the 10th of May 1919, I was born in Greifswald (Pommern) as the son of the government president Magnus Freiherr V. Braun and his Emmy (Nee) Quistorp.

I spent my youth in Berlin where I attended the Prep School and the Government French High School until Easter 1934. Finally, I went to the Herman Lietz School in Spiekeroog, Nordsee, an agricultural boarding school where I passed my final examination Easter 1937.

After the performing of labor service, I began at the Munich Technical High School in the fall of 1937, with studies of chemistry, especially organic chemistry. After the conclusion of the studies for which I received the title of Diploma-Engineer, I became the assistant in Organic Chemistry with Prof. Hans Fischer (Nobel Prize winner in chemistry) for ½ year until I was called up to the Air Force in October 1940. After the completion of flying training and a short stay as a flight instructor, I came to the Heimat Artillery Park II, Karlshagen in July 1943. In Karlshagen, I worked with Diploma Chemist, Heller, as a test bend chemist on the subject of hypergolic fuels for the new development "Wasserfall" in conjunction with the I.G. Farben Industrie, Ludwigshafen (Dr. Haussman). In October 1943, my brother Prof. Dr. V. Braun requested me to work as his personal assistant.

Signed: Magnus V. Braun

MEMORANDUM: INTERVIEW WITH PROF. DR. THEODOR BUCHHOLD.

See Ref. No. SAIC/6, 13 April 1945 for result of preliminary interrogation.

Connection with Peenemunde.

Dr. Buchhold was called to Peenemunde in 1939 along with the following personnel:

Prof. Busch, Electro-technischne, Darmstadt
Prof. Walther, Math., Darmstadt.
Prof. Wagner, Phys. Chem., Darmstadt.
Prof. Heuter, Electro-Tech. (Measurements), Darmstadt.
Prof. Bless, Mech., Darmstadt
Prof. Thum, Machine Tools, Darmstadt
Prof. Wolmann, Schwachstrom Technik, Dresden
Prof. Stasblein, " " , Berlin (now deceased)
Prof. Fassbender " " , Berlin
Prof. Heidebruch, Machinen Elemente, Dresden
(Wolmann, Stasblein, and Fassbender also are considered to be specialists in Fernmelde Technik.).

During the meeting these scientists were told about the large scale developments in rocket-propelled missiles and were given specific assignments. At that time, Dr. Steinhof was the individual at Peenemunde in charge of all of the electrical control and under him Dr. Friedrichs was in charge of development of the steering controls (but not of the Brennschluss control) Dr. Ing. Kirchstein was at that time working with Fassbender in Berlin, where he became associated with development of the W/T Brennschluss equipment. He later was called to Peenemunde and put in charge of all types of Brennschluss control. Mention also was made of Dir. Thiel, in charge of all chemical work at Peenemunde. He was killed in one of the early bombings.

Dr. Ing. Buchhold says that he went to Peenemunde about three times a year on the average. He was given as his assignments the problem of developing a frequency regulating device for the motor generators which were to be used to supply 500 cps ac to the electrical control equipment, and the problem of finding a satisfactory method for measuring the velocity of the missile in order to determine the correct time for shutting off the jet (Brennschluss).

Frequency Regulating Equipment.

The subject was asked to draw a sketch of the circuit employed in this device. His circuit and explanation was substantially the same as that given in report RAE No. El by C. S. Hudson. Further questioning brought out the fact that the mu-metal saturable reactors were used because that type was already available from work on peaking circuits. Two reactors in series were used in order to cancel the ac coltages which are induced in the dc circuits. The familiar "three-legged" type of construction was not used because of excessice leakage. The reactos were manufactured by Hereus of Hanau.

Brennschluss Control.

This project was regarded as of very great importance. Five different institutions were at work on it along different lines.

Prof. Fassbender, Inst. fur Schwingungs Forschung, Berlin, was working on a W/T solution (Verdoppler) which was the first control actually used.

Kreisel Gerate, Berlin, developed the gyroscopic type of integrating accelerometer.

Prof. Buchhold, Tech. Hochschule, Darmstadt, was working on an electrolytic integrating accelerometer.

Prof. Huter, Tech. Hoch. Darmstadt, was also working on an integrating accelerometer

Firma Ott, Kempten in Bavaria. Type of control not specified.

The W/T was satisfactory, but complicated and known to be vulnerable to counter measures. Consequently considerable pressure was put on the accelerometer methods. Dr. Buchhold's control was completed at about the same time as the Kreisel Gerate but was not adopted immediately because it employed electronic valves which were in short supply. (One and one-half to two years ago). However the fact that it is considerably more accurate than the gyroscopic type (approx. one part per thou. as compared to five parts per thou. according to subject) lead to its being put into production about one year ago. Subject says he is certain that the controls have been manufactured but cannot say whether or not they have been used operationally. The device was divided into two parts for manufacturing, namely the Messkopf (acceleration measuring instrument) and the Netzteil (electronic circuits). The former was manufactured by Firma Stotz in Eberbach and was to be made in larger quantity by Siemens, Vienna. The latter was given to Lorenz of Berlin, and was passed on by them to Pulsnitz near Dresden.

The system devised by Dr. Buchhold consists of an ac bridge which is unbalanced by a copper vane mounted on a pivot in such a way that rotational torque is produced by acceleration. The output of the bridge is amplified by a conventional sort of valve amplifier and then rectified by a copper-oxide bridge. The rectified output current is passed through an integrating cell (electrolytic) and also through the coil of a torque motor on the shaft of the integration instrument. This latter connection is in the nature of a feedback circuit which improves the accuracy of the device. The electrolytic cell operates in the following way: When the current, which is proportional to acceleration is passed through the cell it transfers silver chloride from one electrode to the other at a rate which accurately corresponds to the magnitude of the current. When the chloride is entirely removed from the cathode, a sudden change in voltage across the cell occurs which, acting through a second valve, actuates a relay and shuts off the jet. A circuit diagram is shown in Ref. SAIC/6 and a mechanical sketch of the Messkopf made by the subject is attached.

Compensation for errors

The present type of acceleration integrators can be made to give an answer which is essentially

$$\overline{V} = V + kt$$

Prof. Walther is supposed to have made extensive calculations on trajectories of this rocket and to have prepared firing tables from which the value of $\overline{V}$ is determined.

The subject stated that a still more accurate way of compensating for the effect of other factors than velocity on range had been contemplated. This idea involved the use of two integration accelerometers mounted on a stabilised platform in such a way as to measure the vertical and horizontal compounds of velocity. In this case, the Brennschl[illegible] to be determined by the correct value of

$$\overline{V} = V + ks$$

where we believe that s is the distance along the path.

Recent work.

Since the completion of this device, the subject has been working with Dipl. Ing. Muller of Gotenhafen (for about six months anyway) on the development of a frequency regulator for the current supply on torpedoes. This was almost identical with that for the A-4 rocket, he says. In addition, and this is believed to have been his major effort, he has been working on a regulating device to maintain constant field strength on the magnets of the cyclotron at the Kaiser Wilhelm Inst. at Heidelburg. Prof. Bothe and his assistant did most of the work at the Institute, and the subject claims that he was only consulted in connection with the regulating device, and does not know what experiments were being carried on. He was only there twice, he says. Before his device was finished his laboratory was destroyed, and the device was never used. He believed, however that there were several other troubles with the cyclotron, and that satisfactory operation was not obtained.

MEMORANDUM: FURTHER INTERROGATION OF PROF. BUCHHOLD 21 April 1945.

Additional questions were asked of Prof. Buchhold to clear up certain points from the previous interrogation.

The radio method of range control was worked out by Prof. WOLMANN.
Prof. HUETTE and Prof. Fassbender were working on methods that did not differ much. The principle used was coupled tuned circuits with and iron weight that is moved by the acceleration. Motion changes the frequency. The frequency is integrated by a motor which gears to the velocity indicating device.

Prof. OTT was working on a method using a weight and spring. The weight carried a disc integrator which bore against a disc which rotated at constant velocity. The integrating disc bore against the driver disc at a radius determined by the acceleration. Revolutions of the integrating disc were counted to give velocity.

Subject was questioned further about the proposed improvements in his system with the electrolytic cell. First improvement mentioned was the addition of a second winding to the coil of the Messkopf. This second winding was to carry a constant current to cancel out the effect of gravity. Turning the current off permitted the device to be calibrated by gravity. As the missile turns during flight, gravity cannot always be cancelled unless the Messkopf is on a gyro stabilized platform. The next improvement contemplated but not carried out was to mount two Messkopf's on a gyro stabilized platform. Gravity is perfectly cancelled out in each. The axis of the two are not vertical however. One is at what he called angle alpha. This measures the total velocity of this direction. The other is at an angle neared the vertical which he called epsilon. Double integration of this Messkopf output gives distance travelled in that direction. The double integration may be performed either by a capacitor - resistor circuit and another electronic valve added to the circuit he previously gave, or by adding a circuit using two electrolytic cells back to back with a reversing circuit to change the direction of current flow each time the end point of either cell is reached. The finite delta V's are counted and give the double integral or distance to a close approximation. Prof. Walther apparently worked out the optimum angles alpha and epsilon to give best measurement of the four coordinates affecting range, namely the two coordinates of position and the two components of velocity at Brennschluss. They were apparently chosen to give the best cancellation of small errors possible with two Messkopf's instead of four. In summary then, what is measured and made to operate the final electrolytic cell which controls Brennschluss is V_{alpha} plus N $s_{epsilon}$, where N is the proper constant.

Subject worked at Brown-Boveri before 1934, on electric railways for Bavaria, Stuttgart, etc. In 1934-9 he taught at Darmstadt and wrote books "Elektrische Kraftwerke und Netze".

Dr. Ing. LAMBRICH

employed until recently as leader of the development department WKL-O (Waffen Konstuktion Luft) on weapons for use against sea targets - at Rheinmetall-Borsig, Marienfelde, Berlin. Deserted recently to Allies with his assistant since he thinks it senseless to fight on. Working primarily on following projects:

1. SB 800 RS (code name "Kurt") - a weapon against sea targets (preferably not on high seas) ships in inland waters, lock gates etc. Consists of spherical bomb, steel casing 12 mm thick, sphere diameter 75 cm, filling weight 300 kg of H.E. (composition TNT 50: NH_4NO_3 30 AR 20). Rocket attachment as tail unit, very similar in size and construction to that used on PC 1000 RS (known) bomb. Solid fuel rocket, thrust 1250 kg sec, starts 0.6 secs after dropping, burns for 1.8 secs. After burning finished, rocket tail unit jettison, bomb continues as in skip bombing. Bomb tested at Leba and Travemunde. Dropped from Me 109, height 25-30 meters, at range of e.g. 2½ km from ship and speed of 250 km/hr. Found that if rocket tail unit could be tilted downwards angle of impact on sea could be reduced from 5° to 2°. This meant that a gyro had to be used. Powder-driven gyro employed - reaches 10-12000 rpm in 0.3 secs. Made by Lorenz, Dresden.

Bomb has two hydrostatic fuzes running towards center and one time fuze. Hydrostatic fuze operating depth is approx. 8 meters.

2. R 100 BS - development of R 100 M since it has been decided that blast effect of thin cased H.E. method is not sufficient to bring down enough bombers in a formation.

BS 460 Brandsplitter of 55 g. each (th cylinders, length 1.54 diam.) Calculated to have sufficient energy to penetrate fuel tanks and thus set aircraft on fire. Burning time of each incendiary is 0.8 secs (fuzing time?)

R 100 BS weighs 100 kg. Used from fighters. (Calibre 21 cm, length about 1.8 m) Velocity of rocket at moment of disruption - about 500 m/sec.

Launching rail for R 100 BS - length approx 5 cm. Fin stabilized rocket.

Rocket on R 100 BS - thrust 4200 Kg sec, burning time 0.9 sec, range 1500 m. but normally for special Oberon Verfahren about 1200 m.

Intended to use 4 x R 100 BS on Me 262.

3. Oberon Verfahren.

For use with R 100 BS. Components - FuG 217 or 218 (depending on circulability) E242 - gyro gunsight made by Askania, Friedenau. Elfe - an "impulsgeber" (by Siemens, Wernwerk). Anstellwintelger - altitude angle (by Zeiss Ikon, Dresden) Oberon Uhr - clockwork device (by Goesty, Vienna). JG7 at Lechfeld about 4 weeks ago were thinking of trying out R 100 BS without Oberon.

Lambrich 4 weeks ago was told to be generally responsible for putting into operation.

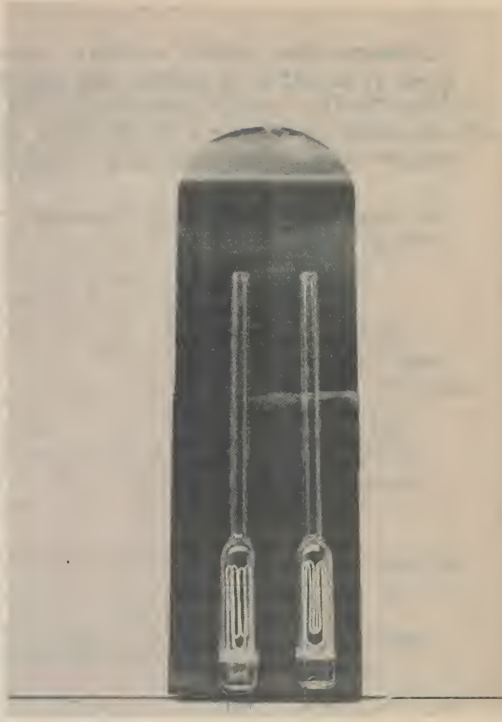
Arado developed the idea but didn't push on with it.

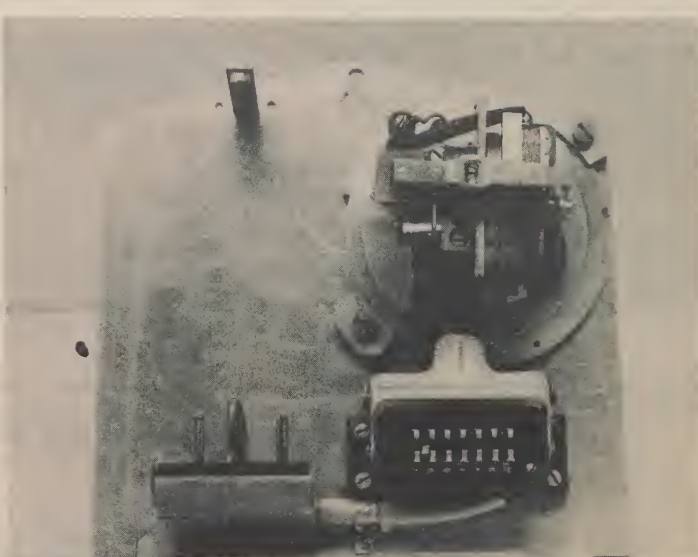
Operation.

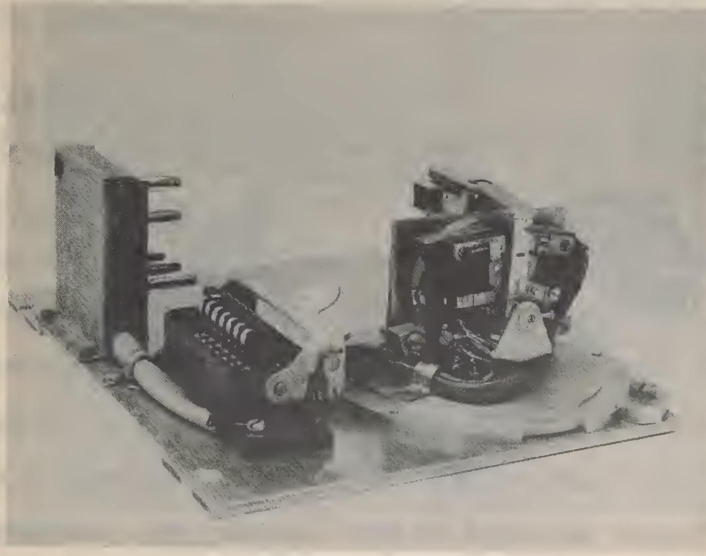
1. FuG 217 or 218 feeds range continuously into Elfe.
2. Elfe supplies impulse when preset distance is reached. This goes to

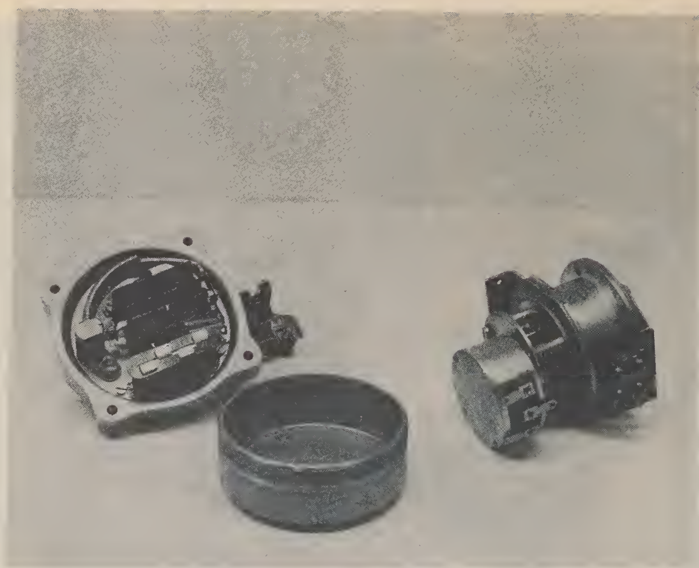
3. Oberon Uhr, which starts. At second distance preset on Elfe second impulse goes from Elfe to Oberon Uhe which then reverses until reaches firing setting. This firing setting determined by following additional devices - 242, Anstellwinkelgeber - which feed their value into calculating mech. of o'clock. Third valve - fuse setting - fed into calc. mech by pilots setting.

Impulse sent from clock operates relay to fire shell. 2 rockets fired at once - second.









Dipl. Ing. Josef Bohm.

Personal Data.

I, Josef Bohm, was born on August 7, 1908 in Unterhimmel near Steyr, Upper Austria, as son of the commercial employee, Josef Bohm and his wife Maria, nee Walter. On September 25, 1941, I married Irene Arnold. The first child, Ulrike, was born in Swinemunde on June 15, 1943. My wife was expecting another child in May 1945. Her last residence was Treba No. 49 near Bleicherode/Sudharz (Thuringia) at the home of Herrn Herrman Wiegand. My parents live in Brux, Am Pressfeld No. 17 in Northern Bohemia.

Education.

After attending the public school in Steyr and the Staatsaberrealgymnasium in Brux (Diploma 1928), I began studying general machine construction at the Technical High School, Dresden. I completed my studies by passing the final diploma examination 6 February 1935. My main subject was that of gearing techniques, especially in the research of intermittently working transmissions.

Industrial Occupation.

Already during my studies (leave of absence) I worked for several firms as a fitter, assembler, draftsman and designer. Furthermore, I supervised the erection of industrial trial models or patterns invented by me on which patents are pending.

Duties at the High School.

From February 1935 till November 1939, I worked as assistant to Prof. Dr. H. Alt in the branch for gearing techniques at the Technical High School, Dresden. There, I picked up a vast amount of special knowledge and information concerning the newest methods for ascertaining gear couplings.

Duties at the Elektromechanischen Werke, Karlshagen.

In November 1939, I was ordered to the Heeresversuchsanstalt, Peenemunde. At first, I took over the designing of testing devices. Later, I was put in charge of the designing office in the section for electro-technical apparatus under the leadership of Dr. Steinhoff.

Signed: Dipl. Ing. J. Bohm.

Josef Böhm, Dipl.- Ing

Worked on the mounting of the control devices in the A4, as well as the mounting of the graphite rudders. Made the vibration safeboxes for the transport of all of the electrical apparatus. The instruments were mounted on two big wooden boards (Holzkreuz) with the idea in mind of having all instruments readily accessible and readily exchangeable.

Before coming to Peenemünde M. Böhm built packing machines for dried soups, conserves tins etc.

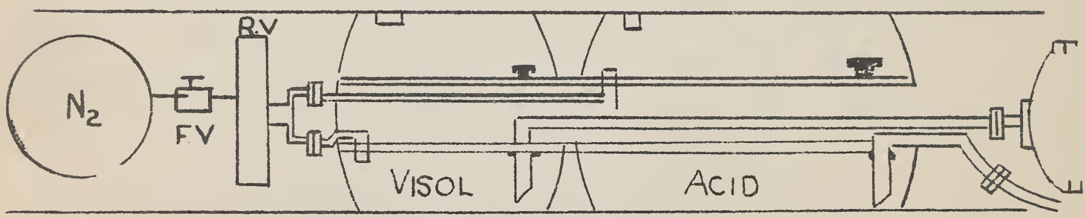
INTERROGATION OF BRINGER

BY: H.A.Liebhafsky, G.T. Gollen, J. Iball, at Garmisch

DATED: 22 May 1945.

Worked on Wasserfall.
Tanks made of 4% chrome steel.

Luftwaffe No. 1604 model - layout below:



They aimed at getting Wasserfall good for storage for 1/2 year before firing.

Every Wasserfall shot had the central pipe duct through the tanks.

Konrad Dannenberg attended a technical school in Hanover, where he took his degree. He left school in 1938, and became assistant to Prof. Newmann at Hanover. He was in the army from Aug 1939 to Oct 1940, after which he was chief designer at Peenemunde.

While there Dannenberg worked in on A-3, and A-5 combustion chambers, but the majority of his work was on the A-4. He knows practically nothing of Wasserfall orTaifun.

He stated that he did not know the cause of airbursts. Dannenberg said that the O2 Steam Heat Exchange was designed by "Bedurftig", and further stated that the reducing valve was heated to avoid cooling due to the expansion of the N2.

Interviewed 19 May 1945

Chief Engineer, Dipl. Ing. Konrad Dannenberg. 16 May 1945

I was born August 5, 1912 in Weissenfels a.d. Saale, the son of the postal inspector Hermann Dannenberg and his wife Klara Dannenberg (born Kittler).

Course of education:

April 1918 - April 1922 -- Public School Hannover.

April 1922 - March 1931 -- Luther secondary school for higher education (prep school) Hannover. Grade of final examination "Good".

April 1931 - October 1937 -- Technical High School, Hannover, specializing in the field of general machine construction. Theme for which diploma was granted: "Atomizing the stream and preparing fuels for the process of combustion in an engine. Grade for final examination "Distinguished".

October 1937 - March 1939 -- Assistant to Professor for combustion power engines, Professor Dr. Ing. Neuman at the Technical High School, Hannover. Worked on liquid Propane, Butane, etc. in conjunction with Deurag, Misburg.

March 1939 - August 1939 -- Attending lectures and practice at the Johann Wolfgang Goethe University with the intention of becoming a Doctor of Pol. Economy. While studying, I was also working at the VDO-Tachometer AG, where I worked as technical assistant in the sales department.

September 1939 - September 1940 -- Drafted into Wehrmacht.

October 1940 -------------- Moved job for VDO-Tachometer AG, shortly thereafter on duty status to Army Experimental Station, Peenemunde.

Previous work in the field of "R".

Enthused by the Opel-Valier experimental trips (1929) on the railroad line Hannover - Burgdorf, I decided to join Eng. Albert Puellenberg who was already working in that field. Our work was done in our free time in the Hannover work shops and later carried out at the "Rakentenflugplate (Rocket Airfield) Vahrenwalder-Heide", but really effective developments could not be carried out since the amount of money on hand did not allow us to go spending it on a large scale for such work. Especially difficult to obtain were the necessary amounts of oxygen and the suitable material as well as the use of same. A special success was the presence at DVL Air Exhibition at Hannover where the 5-to-testing stand was shown as it was later constructed at the Rocket Airfield. The best performance was achieved with a stable small rocket which in 1934 reached an altitude of nearly 1000 meters. The planned parachute landing was unsuccessful because the release mechanism didn't work.

Because of reasons unknown to me, all work was stopped by the NSDAP (Nazi Party) in 1934/1935. Eng. Puellenberg went to Bremen where he carried on with his work with a small group of students.

In 1940, through recommendation of Eng. Puellenberg, my application for service with H.V.P. came through and I was assigned by the superintendent for the development of power units, Dr. Ing. Thiel, to work as specialist for combustion questions with Dipl. Chem. Heller. Together, we developed the atomizing system for the assisted take-off devices B-7 and B-8 as well as the 1, 4-to-container as forerunner to the development of the 25-to-oven. At that time, the following were working in conjunction with us:

My fomer teacher Prof. Dr. Ing. Nueman of the Technical High School, Hannover.

Dr. Pauer and his assistants from the Technical High School Dresden.

Dr. Ing. Knettner, Ing. Lindenberg, Dr. Ing. Mertz.

Since Dipl. Chem. Heller began specializing more and more on fuel questions, I took over, after a short time, the field of "R-Behaelter" (R-tanks) myself, and developed at the test bench in Peenemuende, a series of 25-to-R-containers which went into use on the A-4.

Could not go to extensive trouble to develop a jet propulsion unit suitable for mass production because of time and lacking capacity of work shops and testing benches. The continuation of developments were done mainly by the Technical High Schools, Dresden, Prof. Dr. Ing. Pauer with associates as stated above and by the Technical High School, Berlin, Prof. Dr. Ing. Beck with several associates.

When the A-4 went into series production, I was transferred to the preparation of cells and engines for the A-4. As a result of my experience, I was able to be of great assistance to my co-workers, Eng. Schulze and Eng. Zoike.

As representative of the director for development and construction, I undertook the post of chief constructor besides similar work attending to the project department under its director, Dipl. Eng. Roth, the statics department under Dr. Eng. Raithel, as well as the experimental department under Dr. Eng. Bornschauer. Constructional work groups were also conducted by Eng. Schulze for A-4, by Eng. Patt for "Wasserfall" and by Dipl. Eng. Schlenfelen for "Taifun". All questions of fuel were delegated to Dipl. Chem. Heller and problems of the testing of materials to Dr. Ing. Stenser, in close cooperation with German industry and various high schools. For problems of representation, the graphist, de Beek with a team of outstanding artists and technicians was at our disposal.

For the specific problems, a working group or other composite team knew the best preliminary conditions, as through the long years of experience of the leading co-workers and the long years of experience of the leading co-workers and their interest in the work as well as their love for the subject. The best working conditions were created. On this basis, the technicians can be considered as the best experts in their own field of work.

Signed: Konrad Dannenberg.

Interrogation of Dr. Phys. M.J.H. DAVID, 13 May 1945, by Dr. R.W. Porter and F/Lt. Stokes, at Partenkirchen.

Dr. David came to Karlshagen about 7 January 1943 at which time preliminary investigations on Wasserfall were just starting. At XXX this time the effect of Allied air attacks was becoming increasingly important, and a frantic effort was being made to find effective counter measures. The Wasserfall was an attempt to apply the techniques of the A 4 to this problem.

At about the time Dr. David came to Karlshagen, his father was arrested and eventually put to death for expressing critical opinions. Consequently Dr. David was not particularly concerned about the success of the project. He felt that it did not appear to be promiXsing anyhow because he did not believe it could be completed in time. They were ordered to adopt existing devices such as standard aircraft gyroscopes, the A-4 Mischgerät, and the A-4 rudder servo mechanism, and the remote control of the existing Kehlgerät (used on Hs 293.) Most of the equipment was not ideally suited to the Wasserfall application, particularly the servo mechanism which Dr. David says was not fast enough or powerful enough to follow the rapid XXXXXX motions required.

A number of rockets were fired with remote control but none using a target. According to Dr. David, the joystick control was used simply to test whether or not the rocket could be made to follow a prescribed course with visual XXXXXX observation.

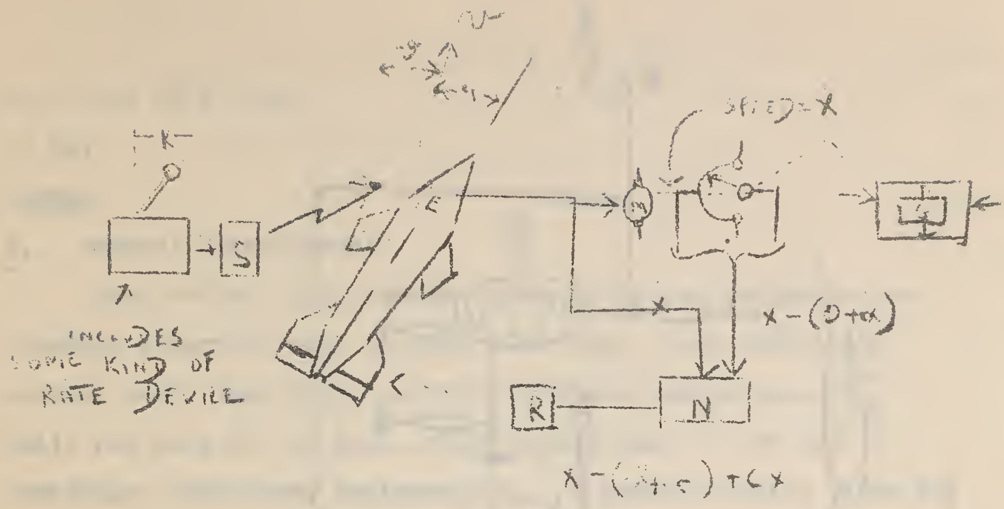
Dr. Elfers was the man, according to Dr. David, who was largely responsible for the servo control and overall stability problems at Wasserfall.

The special work of Dr. David was the design of an electrical model of the control system for Wasserfall. The differential equations on which this model was based are given in Fig. 1. Using this model, which was at that time essentially complete, he had started to work out the trajectories for various assumptions regarding the motion of the target etc., when the Americans approached Neue Bleicherode and he had to quit.

The circuit of the basic electrical integrator is shown in Fig. 2. Its operation is as follows; An XXX AC signal is fed into the first valve, amplified, and rectified either by means of diodes or dry rectifiers. The resulting d.c. voltage, which is of rather large magnitude, is connected across a resistor and capacitor in series. If the resistance and the capacity are both large, the resulting voltage across the condenser will approximate the value of the integral. This voltage is modulated by the rectifier circuit shown, and again amplified. Part of the output is coupled back into the input circuit in order to compensate for the voltage across the condenser. In this way a very accurate integration can be obtained. Over a period of fifteen seconds it is believed that any reasonable function can be integrated with an accuracy of the order of one percent.

Some test firings were made using a different control system, employing rate gyros, according to Dr. David. Work on this system was carr- i l out by Dipl. Ing. Klein.

R.W. Porter.



$$\mathcal{M} = K + BK \qquad (1)$$

$$x = A\mathcal{M} \qquad (2)$$

$$\ddot{\alpha} = -D\dot{\alpha} + C\left[-\alpha + E\int_0^t (\dot{x} - \vartheta)\,dt + Fx\right] \qquad (3)$$

$$\vartheta = G\Delta\vartheta + H\dot{\vartheta} \quad \text{where } \Delta\vartheta = \vartheta - \Theta \qquad (4)$$

(Θ is the theoretical angle obtained from calculation)

$$\dot{z} = v \cdot \Delta\vartheta \qquad (5)$$

$$\dot{\varepsilon} = \frac{v}{r}(\Delta\vartheta - \varepsilon) \qquad (6)$$

D is $\dfrac{\text{aerodynamic damping}}{\text{moment of inertia}}$

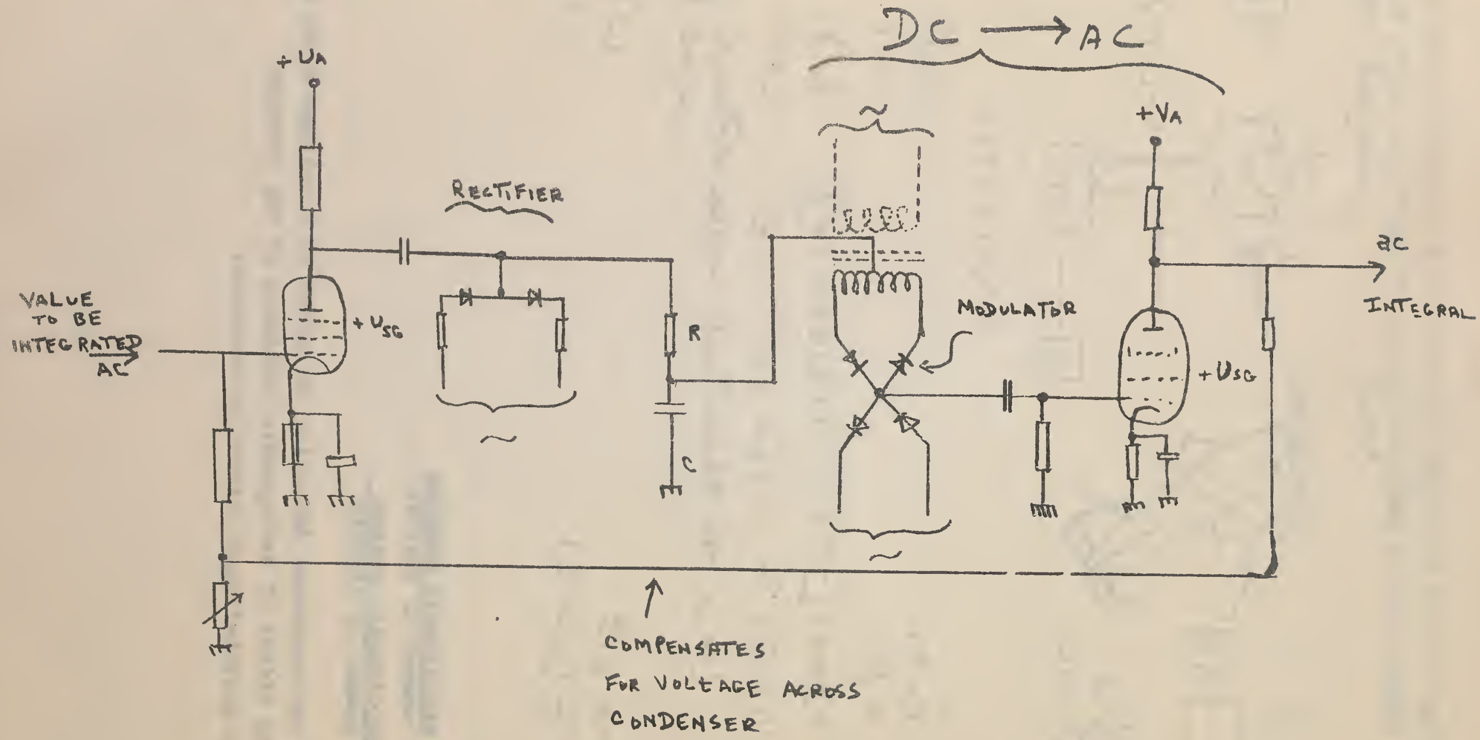
C is $\dfrac{\text{aerodynamic moment}}{\text{moment of inertia}}$

E,2F, are constants depending on amount of X voltage which is introduced, and on the effect of aerodynamic unbălance of the rudders.

G is a gravitational correction constant.

ELECTRICAL INTEGRATOR (SCHEMATIC)

FIG. 2 - ELECTRISCHE INTEGRATIONS STUFE
(SCHEMATISCHE AUFZEICHNUNG)



Dr.- Ing. Kurt Debus

EC 227

Career.

1. General particulars:

Born 29 Nov. 1908. at Frankfurt (Main) as the son of the merchant Heinrich Debus and his wife Nelly, (nee Graulich). Married on 30 June 1937, to Irmgard Helene, nee Bruckmann. Child Ute born 20 May 1940, child Sigrid born 20 Nov 1944. Residence: Darmstadt, Hohlerweg 21. At present family lives in Hof Eich near Gelnhausen.

2. Schooling:

Began Easter 1915 at Klinger- Oberrealschule at Frankfurt (Main), later Liebig- Oberrealschule. Finished secondary school in 1928

3. Practical training for Studies:

Easter till fall 1928 and in between various semesters totalling one year practical training in the "Adlerwerken A.G. Frankfurt. Machine fitting, lathe, milling machine, tool making, and erecting, etc. Easter till Fall 1931 six months practical work at "Voigt & Haeffner A.G." Frankfurt. Pattern making, foundry, erecting of fixtures and apparatus inside and out, testing field.

4. Studies:

Beginning Winter semester 28/29 Technical High School, Darmstadt. Training course in Electro- techniques. Fall 1934 Main examination for diploma in high tension techniques. Main subjects: Theoretical Electro techniques Elect. measuring techn., high tension technique, construction of elect. machines, electric nets and installation, technical theory of heat.

5. Practical activity:

Beginning Oct 1935 till today assistant to Professor for theoretic Electro techniques and high tension techniques, Prof. Dr.-Ing. E. Hueuter (Peterson) at the Technical High School in Darmstadt. Chief Engineer since 1939.

Activity:

1. Execution of practical work and exercises, general education work.

2. Execution of measuring in industrial installations and network as well as adviser to various firms.

3. Development and testing of special apparatus for various firms, military services and authorities.

4. Research work in the field of mensuration, in theor. electrotechnique and high tension technique. Especially the development of a process for measuring high-tension-shock occurrences with the usual measuring instrument. Published ETZ 1940. Distinguished himself and had degree conferred on him in Fall 1939.

5. Activities while instructing and at the EW:

Beginning Fall 1939 besides educational work, worked on developments for EW. Especially development of small pressure gauges for measuring models in a wind tunnel, suitable for dynamic measurements in the reach from 1 "ata" to a few "Hg".

Beginning Oct 1943 ordered to EW. At first experimental engineer on test stand A-4 (Electrical sector and controls), later organizing chief for erection and clearing for action of the first motorized ground installation. Starting March 1944 section leader and supervizing experimental engineer forcontrol (steering) and electrical questions at test stand for A-4 and finally superintendent of the A-4 test stand and the test firing stand of the A-4

..., 1o May 1945

Signed;KurtDevus

Interrogation of Ing. Dhom, 21 May 1945, by F/Lt. Stokes and Dr. Porter at Partenkirchen.

Ing. Dhom came to Peenemünde in August 1938. At first he worked in the "Messhaus", where values from all the test stands were wired, to be measured and recorded. His particular job was to install measuring apparatus, such as devices for recording the operation of valves, etc. After 1940 he went to the H.F. center where he worked on various projects for Dr. Wolmann (presumably connected with the "Verdoppen" Brennschluss control).

About the beginning of 1942 he started work on dezimeter transmitters and receivers. His principal project was an oscillator which was used in connection with some receiver on the A-4. (He would not be more specific) The oscillator used a 1-watt triode LD-1 Telefunken. Tests were carried out according to Ing. Dhom in an aircraft, the frequency of the oscillator being picked up and measured on the ground. This work was done under the direction of Dr. Lange.

Asked about difficulties with the "Verdroppen", Dhom replied that there were difficulties, but they were always traced to the equipment itself and not to any unusual phenomen.

Recently he was assigned to work on the "Scholtuhr", a constant speed motor with a contactor which accurately measures the required charging time for the I-gerät. It operates from a frequency-stabilized 50 cycle/sec source. Other than these generalities, he claimed to know nothing about the electrical Brenschluss controls.

R.W. Porter.

Interrogation of: Konrad Dannenberg, Kurt Patt, Goddfried Rosenthal (interpreter), Heinz Giese, Burhose------------By E.H. Hull, at Garmisch-Partenkirchen on 6 June 1945.

These men are the designer-drafting type so tend to give a more practical story than Von Braun who confuses what he hopes to do, with those things which have been reduced to practice. The purpose of this interrogation was to determine the details of piping and valving in C-2.

N_2 is used in the spherical pressure flask since it can easily be obtained dry as a by-product of liquid oxygen plants. Air could probably be used as well but it would have to be dried and there might be some trouble due to the contained O_2.

These men did not know any details of the N_2 heating scheme, or the nozzle design described by von Braun on 5 June 1945 as these devices had not emerged from the experimental stage.

Fig. 1 shows a schematic diagram of the plumbing system of C-2. Part no. 4 is a powder operated diaphragm valve sketched in Fig. 2. An electrically ignited powder charge forces down the piston tearing open the diaphragm allowing high pressure N_2 to flow to the regulator 5 of Fig. 1.

(For details of the pressure regulator see the interrogation of Von Braun, Dannenberg and Klausz on 7 June 1945 which clears up misstatements made during this interrogation.)

The regulated air supply is led to the two reactant tanks past a safety valve 6 (Fig. 1) and thru two burstable diaphragms 7 to prevent any possible mixing of reactants during storage. These diaphragms burst at 10 atü. Tank pressure is 25 atü.

Flexible tubes 10 insure that the tank outlet will always be submerged during radial accelerations of the missile. The pipes are made flexible by means of a stainless steel bellows section which allows angular movements but is stiff axially. A low natural frequency is obtained without adding weight to the bottom of the pipe. Clearance between the tank bottom and pipe is about 20 mm which is sufficient to make the entrance area at least equal to the pipe area.

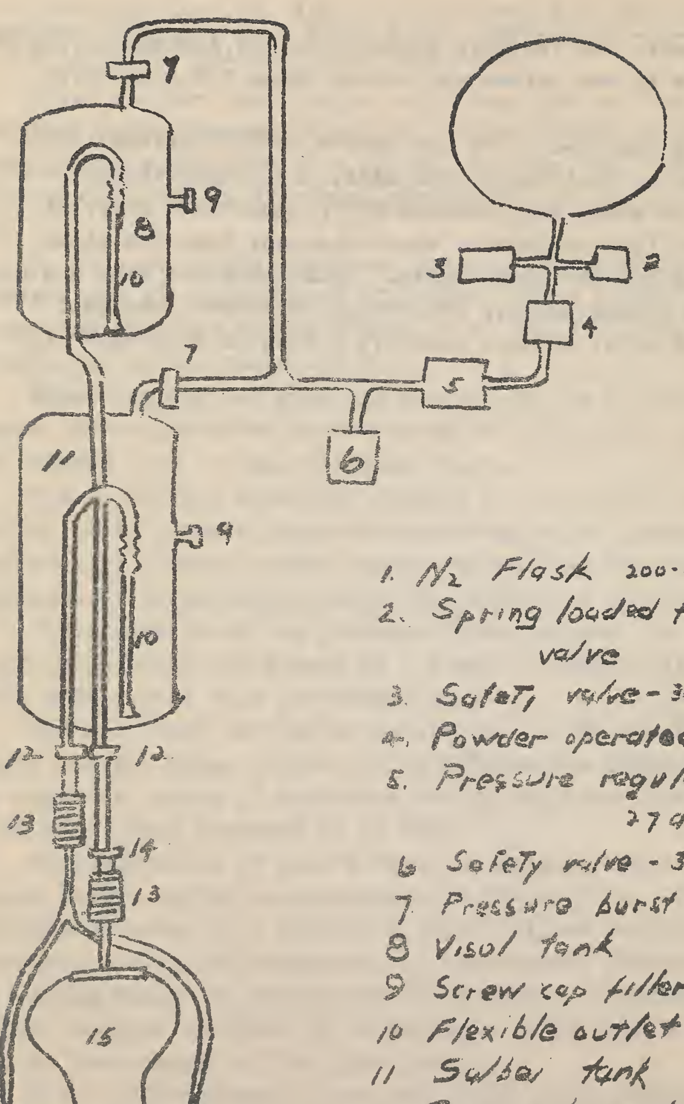
These interrogatees claim that there is no mechanically operated, interconnected valve with time delay for the Visol in the reactant pipes at 12. Instead they would put there two independent diaphragms burst by tank pressure.

The expansion joint 16 of Fig. 1 is shown in greater detail in Fig. 3. Holes are placed in the circumferential ring to reduce resistance to Salbei flow.

A section thru the venture at the exit is shown in Fig. 4.

The combustion chamber and venturi, whose principle dimensions are XX hown in Fig. 5, is made in two halves and welded along the lengthwise seams.

Fig 6 shows what is reported to be the nozzle design intended for production when the move to Bleicherode was made. In flight tests these nozzles were aluminum but steel was intended for production. Pairs of jets squirting the same fluid impinged a short distance from the plate where the streams fanned out at ight angles. This fan mixed with a similar fan from a pair of jets placed nearby, delivering the other reactant. There were about 400-500 holes in all, each 1.5-2.5 mm in diameter. All holes were drilled.



1. N_2 Flask 200-250 atu
2. Spring loaded filling valve
3. Safety valve - 300 atu
4. Powder operated valve
5. Pressure regulator 27 atu
6 Safety valve - 35 atu
7 Pressure burst dph.
8 Visol tank
9 Screw cap filler plug
10 Flexible outlet tube
11 Salbei tank
12 Pressure burst dph - 10 atu
13 Bellows expansion joint
14 Orifice restriction
15 Combustion chamber
16 Expansion joint
17 Salbei distributor

Fig 1

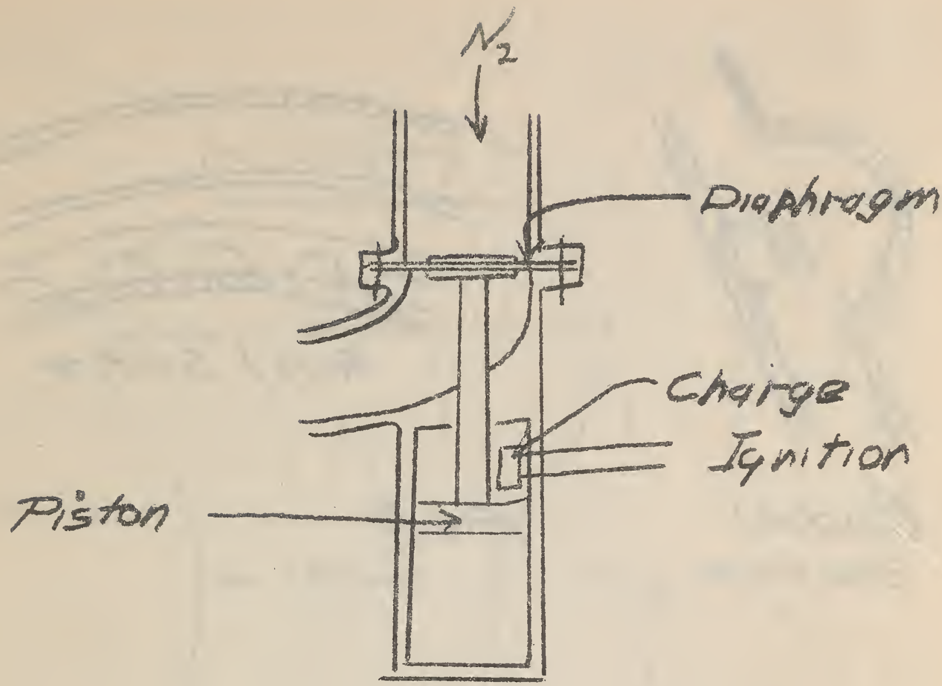


Fig 2

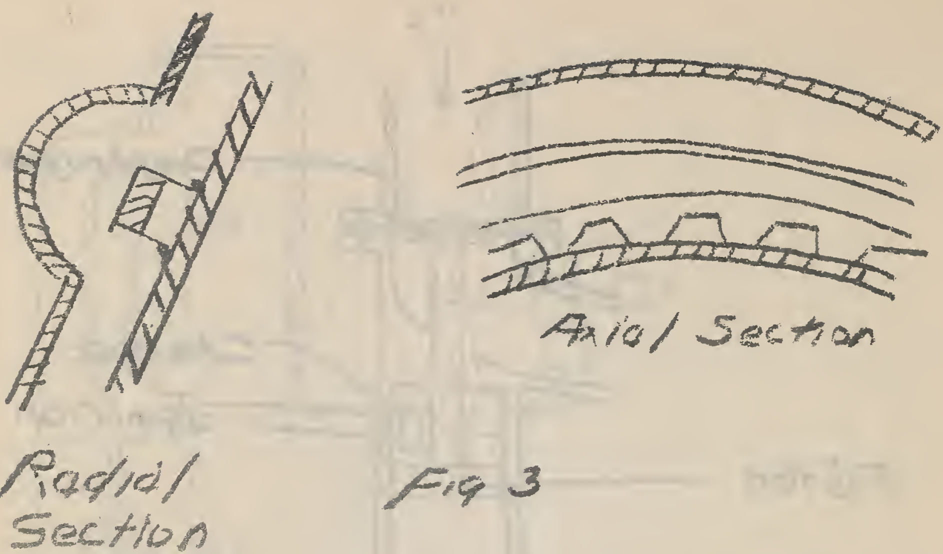


Fig 3

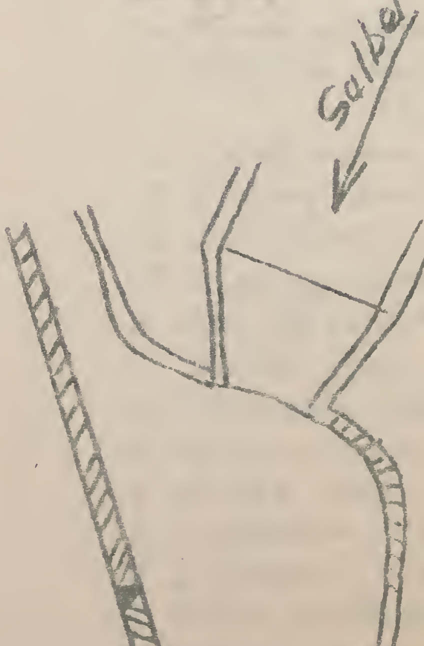


Fig 4

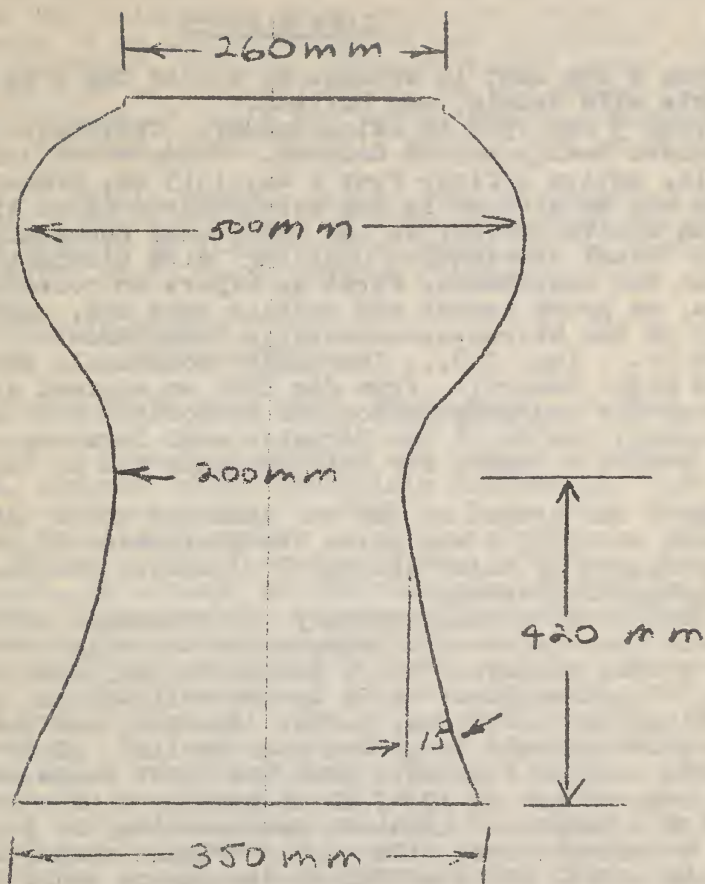


Fig 5

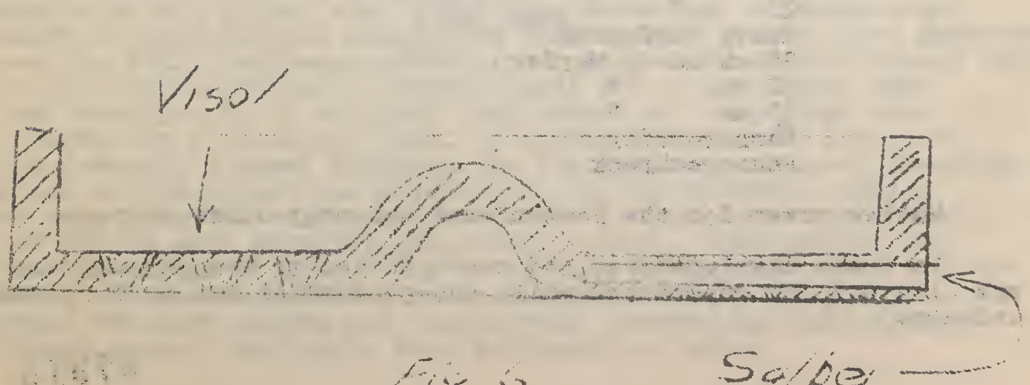


Fig 6

Dr. Ing. C.H. Walter Dornberger
Major General

17 May 1945

Life History

Born 6 Sep 1895 in Grissen as son of the druggist Hermann Dornberger and his wife Hedwig, nee Roltsch.

Married 3 Sep 1942 to Alice Raeder. Childless.

Attended Realgymnasium Grissen. Volunteered 3rd Foot Artillery Regt 2 Aug 1914, active officer from 1 May 1915 on, prisoner of war 3 Oct 1918 after the war an officer in the Reichswehr----After the war (1926-1929) studied as active officer in the Technische Hochschule, Berlin (Hochschul Offizer). Final examination Dipl-Ing "with distinction". From Jan 1930 on, in the War Department, first as expert on rockets, and, upon later expansion, as group leader and section head and, simultaneously, as commander of the Heeresversuchsstelle Peenemünde.

1934 Dr. - Ing. C.H.,, Technische Hochschule Berlin. 1 June 1943 appointed Major General. From Jan 1944 on charged with the special use of the army for the preparation and introduction of A-4. From Jan 1945, simultaneously leader of the "Arbeits stub Dormberger" in the Reichs Ministry headed by Speer for all V-Weapons and AA rockets.

"When I was placed in the War Ministry after the completion of my school work in 1930, I was given the assignment of developing rockets for for war purposes by Major General Dr. Becker, who was then in charge of the Amstgruppe Prüfwesen.

At that time, a small factory in Wesermünde making black powder rockets for sea rescue work represented the only German activity in the field of powder rockets. There was no factory making rockets for war purposes. I had at first to do my own building and to place orders with various firms for individual parts. Assembly and testing were carried out at a proving field or ground near Berlin. After initial difficulties the results were so favorable that the first large scale trial with troops could be carried out in 1934, 10 cm rockets with a range of 6 km being used. With a weapon of lightest construction, it proved possible to saturate a definite area with highly brisant ammunition. In this way, part of the normal field artillery assignment could be carried out by the simplest means imaginable. There was next a transition to smokeless powder and ignition, and temperature-sensitivity problems had to be solved. Then, after the construction of simple launching devices, the following were developed in rapid succession:

15 Cm Nebelwerfer (Do-werfer)
21 "
Heavy Wurfgerät
28 cm heavy Werfer
32 cm "
35 cm "
Panzerwerfer
Panzerschreck

Motive power for the Panzerfaust and many other weapons.

In these developments, the construction of weapons and munitions was always in my department while the production was in the hands of industry

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The first use we made of these new weapons only at the beginning of theinvasion of Russia even though their development had been cancluded in 1939, sufficient munitions were availabel, and trained troops were ready. The spectacular success of the 15 cm Nebelwerfer on all eastern fronts in spite of the relatively small explosive charge of a single rocket is due namely to my introduction ofa new instrument -that of the so called "DOV projectile", whcih in contrast to all power rockets had the pay load at the base of the projectile. The following firms were active in the development of fuels for powder rockets thatleave little smoke: WASAG, DAG (formely ALFRED NOBEL), WOLFF & SON in Walsrode.

In the field of liquid rockets, there were in Germany from 1930 to 1932 onlyviolently feuding groups of inventors, when efforts were doomed to failure because of a shortage of money and an absence of fundamental scientific work. These were as follows:

Max Vallier
Friedrich-Wilhelm, Sander
Heyland A.G. Berlin-Brietz
Winkler
Rocket Flying Field with Prof. Obsth, Nebel, v.Braun andothers.

All the groups of inventors dreamed and talked of travel to the moon. All of them, however lacked sceintific background, exact technical research and alldevelopmental activity. I was well acquainted with the signifiance of the liquid rocket as the revolutionary technical discovery of the 20th century. In order to make progress, the foundation had first to be laid. An attempt at the beginning of 1932 to obtain agreement amoung the inventors or to interest industry missed fire. I therefore decided in the summer of 1932 to take a hand in this field myself. After the necessary approvals, a small trial field was set up on the Kummersdorf proving ground and several engineers such as von Braun, Riedel and Rudolf were enlisted in the fall of 1932. In 1932 and 1933, the proff of the functioning and the reproducibility of liquid rocket-propulsion were established through tedious fundamental scientific research and development activity. The choice of fuels was on the basis of performance diagrams and of availability in Germany. Standing day and night at the construction bench and in the workshop, we calculated , drafted and finished the first combustion chambers for 300 kg. thrust. The work progressed so that already in the summer of 1934 a start could be made in Borkum to a height of 2 km. with a small rocket(A2) of 300 kg. thrust and stabilized by a rotating payload. In the interium, propulsion units with thrusts of 1000 and 1500 kg. (exhaust velocities 2000-2100 m(?) /sec and specific fuel consumption of 4.5 g./kg. sec.) had been developed at Kummersdorf and tested on special test stands. It soon became obvious that Kummersdorf was too small for large rockets; and that furthur development would have to be on an appreciably broader basis and require much more money and more people if a liquid fuel rocket of long range were to be successful in a resonable time. It proved possible to interest the High Command, General Fritsch, the Air Ministry, General Kesselring. Peenemünde on the outset was selected as an experimental station because here alone it was possible to have in Germany a range along the coast of 500 km with suitable observation posts. Construction was begun in the middle of 1936. At a total cost of approximately 300,000 gold marks, there was constructed in Peenemünde in a few years a completely but most modern and technically interesting installation even though ground conditions were unfavorable. After

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After the necessary facilities (highvelocity wind tunnel, work shops, electrical facilities, test stands, ships, planes, and transport facilities) had been installed, the developmant made great strides. It soon became obvious that too great jumps initially would lead to set backs. Consequently, A 4 had for the moment to be relagated to the background. The smaller A 5 was inserted as an intermediate in order to study control, aerodynamics and stabilization. Hundreds ofA 5's were fired in the period 1936-1942. Only with this experience and with the results of wind tunnel investigations available was it possible to proceed with the construction of A 4.

The requisites for success were thgough prolonged and productive combustion experiments for the propulsion ,experiments for pumps and valves, controlled experiments and direction beam experiments, experiments on materials, developments tests on all partsby thousands of engineers,and experts. On the 3rd. of Oct 1942, the first range trial succeeded with satisfactory accuracy. Half of 1943 expired before sufficient experience was available so that the order to begin the manufacture could be given. The air attack on Peenemünde on the night of 17/18/-8-43 did not essentially hinder the work. The develop-ment was complete. The manufacturing proceeded in any case at another location, only the settlement had been destroyed. Even though approx. 65,000 changes were made on V-2 during manufacture, still by and large the weapon introduced in 1944 was the weapon completed in the middle of 1943.

The development of this difficult device necessitated the exploration of a new technical field, and it consequently encountered enormous difficulties. These difficulties were similar to those which would have faced Wilbur Wright ifone had demanded of him in 1902 that he build in three years a completely automatic flying fortress. In addition to the technical difficulties , I had to overcome in my job, the lack of faith and the skepticism of important people in the government, and of my collegues. After the program was reduced in priority in 1939 and a a part of the civil employes were withdrawn, progress could be made in the next years only with the help of Field Marshall Von Brauchitsck, who placed soldiers from the front at our disposal as engineers and workers, and with the help of Generalbau-inspektors Speer who carried out construction for us. If I had had complete backing from the beginning of the war, A-4 could have been introduced 1-1/2 to 2 years earlier.

After the first development was completed, I also had to carry out testing,organization and training of troops. This proceeded until the middle of 1944. In these trials, many difficulties arose which had not been observed in Peenemünde. In the first place there appeared a weakness in A-4 such that 30-40 % of the devices disinte-grated in air at a height of 500-3000 meters before striking the earth. Experiments to eleminate this weakness took months. An improvement seemed to occure in the middle of 1944. The 5 % dispersion was 4x4.5 km, which was difinitely better than the longest range guns which had only half the range of A-4. Even tho the development could be considered as no means closed and I objected to immediate introduction of the weapon, total responsibility and the time of introduction were placed in the hands of the SS after events of 20 July 1944. I was left in the position of technical advisor and in charge of home organization.

A large number of interested groups of technical and scientific institutes were consulted and representatives of industrial groups were concentrated at Peenemünde where theclosest exchange of ideas was continuously possible and where in the very lavishly-equipped laboratories. It is only due tothose actions and the fanatic cooperation

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... of the whole staff of Peenemünde, which did not allow itself to be discouraged by failures that the dream of humanity to explore interstellar space was realized in its first stage.

Even tho the first step of advance into space owes its existance to Military commands, yet the proof has been obtained contrary to all opposing theories - that space may be mastered for peaceful purposes, that it is only necessary to make certain that the experience once gained is not lost. That state will be first in space which has first the courage to make a clear decision. The stratisphere travel rocket will come as certainly as the modern locomotive followed the first Stevenson locomotive.

Apart from the long range rocket which was my principle and favorate assignment there were developed in Peenemünde the following:

Liquid Rocket ATO units for Bombers
Rocket Aircraft
Controlled and Uncontrolled AA Rockets

Even tho these developments ~~were~~ for various reasons were not introduced in this war, yet the work on the long range rocket and the work on the stabilization & control showed that these developments will have many uses!

Inspired by what has been achieved, our thoughts were occupied from the beginning with furthur possibilities. Our experience showed clearly that it would have been futile to lay out immediatly rocket travel to the moon and to the stars. Development can, as in all technically revolutionary discoveries proceed only stepwise if decisive setbacks are to be avoided.

After A-4,A-9,A-10 were designed and planned as the first project, the necessary intermediate steps being considered. This was to be a travel rocket in which one could travel in about 40 min. from Berlin to New York and land there. The perliminary work was for the large part completed and wind tunnel for 300 m/sec velocity had been projected and the construction provided for. Furthur work was hindered by the war.

The furthur possibilities for the future are available: scientific high altitude rockets, a station in space, travel to the moon and to the stars. Even if the greatest distances in space can be reached after atomic disintegration is available as a fuel- assumptions concerning this are being realized- still it is possible with the present fuels it is possible to reach distances hitherfor considered unattainable.

The forgoing developments and projects were carried out under my direction in the years 1930-1935 by a group of distinguished fanatic scientists and experts. Thereby new regions were opened to humanity, where scope and meaning cannot be highly enough evaluated.

Dornberger.

INTERROGATION OF GEN! DORNBERGER AT PARTENKIRCHEN - 15 May 1945.

By: Dr. E.H. Krause
Lt.(j.g.) P.W. Wilkinson, USNR

Gen. Dornberger was interrogated concerning his knowledge of the German guided missile program. He was associated primarily with the A-4 and Wasserfall projects but did display a considerable knowledge of most of the other ground to ground, air to air and ground to air projects which were underway.

In, January 1945 he was placed in charge of all projects falling in the catagories listed above. These were at that time some 48 ground to air projects alone in various stages between proposal and development. He reduced this to five projects, namely, Schmetterling (Hs 117), Enzian, X-4, Rheintochter and Wasserfall. The X-4 was chosen over the Hs 298 because it was lighter. Wasserfall was included because it was the only supersonic missile. During February the development of these remaining five was also stopped and all effort was concentrated on the R 4 M and Taifun rockets.

During the entire interrogation Gen. Dornberger was very obliging and answered all questions freely. He was questioned in some detail on information which had previously been obtained from the Osenberg files in order to check his reliability. His statements were in general agreement with these files. As a matter of fact he continually cautioned us that his figures were approximate and that we should obtain the exact figures from Von Braun.

WASSERFALL

This is a ground to air guided missile patterned after the V-2 and was the only missile for this use which operated at supersonic velocities. It's characteristics were approximately as follows:

Length 6m

Diam. 75 cm

Max Altitude 16Km

WASSERFALL (continued)

Range	20 Km	Max Velocity	600 m/sec
Fuel	Visol	Burning Time	45 sec
Oxygen	HNO_3	Launching Angle	90°
		Explosive	100 Kg
		Empty Weight	1.5 Ton

As a first step in the development ~~of~~ a radio control system of guiding was used. Thirty-five models of this type were test fired of which 60 - 70 % failed. Launching and stabilization were the same as in the A-4. "Line of sight" flight path was used.

Because of the limitations of clear daylight operations several programs were initiated to provide homing in the Wasserfall. Also a proximity fuse was to be added. The general idea was to use a cm. radar to track the target and by means of second similar radar bring the missile into the beam of the first radar. The missile would then automatically ride the beam to within 3000 meters or less at which point the homing system would take over. In actual test no homing system has operated beyond 200 meters. The homing system under development and the firms working on them were as follows:

Infra-red	ELAK-Oberschleswig	Captured by the Russians
Optical	Reichspost-Forschung, Berlin	
Acoustic	ELAK - Vienna	
Doppler(Radio)	Siemens	

The radar was a 3 - 6 cm job completely developed by Telefunken but never produced . Prof. Von Braun and Ober Lt. Netzer can give more details on this.

Although Wasserfall, because of its supersonic speed, was one of the most hopeful of the A A missiles its development was stopped in March 1945 along with the rest of the few remaining guided AA projects inorder to put more effort on simple non-guided AA rockets.

R 4 M

Air to air rocket carried and launched from under the wings of fighter aircraft. Development started in Jan. 1945 and was in operational use in March 1945. During the month of March 76 forays were made using these rockets and 72 allied bombers were brought down (ME 262).

Before launching, the rocket has the shape of an ordinary shell having no wings or fins protuding. After launching a ring releases four tail fins which snap outward into place.

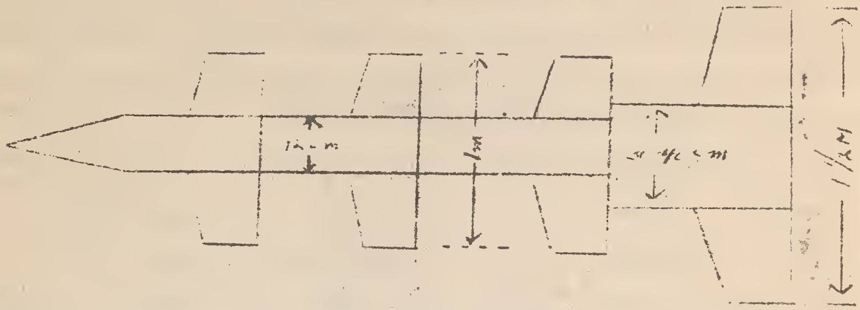
The general characteristics are as follows:

Length	70 cm	V max = 450 m/sec	
Diam	5 cm	Fuel	di-glykol (powder)
Weight	3-4 Kg	Effective Range	800m
Explosive	500 gm		

Although 500 gm of explosive are used, the use of a large number, which will naturally disperse over guite a vloume, makes them very effective. A single fighter can carry and fire 42 of these similtaneously. Because of the small weight oonly contact fuses are used.

RH INBOTE

Four stage, long range, ground to ground solid fuel rocket built and developed by Rheinmetal Borsig. It looks about as follows:



Length	6m	Total Weight	1-1/2 Ton
Range	160 Km	1st, 2nd, 3rd Stage	-6 wings each
Fuel(total)	500 Kg (powder)	4th Stage	12 Wings
Explosive	20 Kg		

The operation consists of firing the first stage in launching and each successive stage by means of a time fuse. The stages are push-fit assembled in such a way that when a given stage is fired, the stage behind it is blown off.

These were used operationally against Antwerp last November or December being fired from Zwolle. Approximately twenty were fired from eight firing ~~xxxxxxx~~ positions. Gen. Dornberger states that the dispersal for a 160Km range is about 160 Km and that in general the device is impractical because of too much gear for to little payload. It was used operationally only because of the insistance of G Gen. Kammler.

T A I F U N

A ground to air liguid rocket, the development of which is not complete. Launching takes place from a rock very similar to the "Do gerät" (named after Gen. Dornberger). It consists of a framework of rails capable of launching 65 rockets simultaneously. It was planned to fire these with the aid of a standard optical fire control system. Operational use was planned for July 1st.

The characteristics are:

Length	220cm	Vmax	1200 m/sec
Diam	10 cm.	Explosive	500gm
Max Alt.	12 Km	Fuel	Visol
Effec. Range	12 Km	Oxygen	HNO_3

Gen. Dornberger gave two reasons for using liquid rather than powder fuel in this rocket.

1. Powder was very scarce and badly needed elsewhere.
2. Because of the more uniform burning of the liquid fuel a smaller dispersion resulted. He quoted the accuracy of the liquid jobas 1:1000 as against 1:100 for the powder.

E N Z I A N

A ground to air radio controlled airplane-like missile. The development was by the Deutsche Versuchs Anstadt fur Luftfahrtforschung (DVL) and the firm Holzbau-Kissing at Sonthofen!

The general details are as follows:

Length	3m	Vmax	280m/sec.
Span	3.5m	Intelligence-	Radio Control
§§§Explosive	30-50 Kg	Construction	Wood
Fuel	Visol		
Oxygen	HNO_3		

§§§ The Osenberg figure was 300 Kg but General Dornberger states this could not have been correct.

Gen. Dornberger stated that since this was a two-winged missile and turned by means of ail aerLerons in the wings, requiring a bank, only a prusuit course was practical! When he took over in January, this project was the first of the five active AA projects to be dripped because of the turning complications.

A - 4

Gen Dornberger made various general remarks concerning the A-4 which may or may not be known but are included here for completeness.

Development work on the A-4 has been going on for the past 12 years. The site at Peenemünde was chosen because it was the only place in Germany where an all water path of 500 km could be obtained within German territory. The path was from Peenemünde into East Prussia with obser ation stations dispersed all along the Baltic coast. Construction of Peenemünde was begun in 1936 and was operating by 1937. The total cost of Peenemünde to date has been about 300 million goldmarks. It was completely blown up before the Russians moved in.

A total of 5400 A-4's were built of which 3600 were fired against the Allies. The cost of the first production A-4 was about 1-1/2 million marks but the final cost was reduced to 37,000 marks. This cost was

A-4 (continued)

contrasted to that of a German bomber costing 1.8 million marks and having a life of about three trips against England.

Radio was almost always used during test firings both for telemetering (24 channels) as well as for flight path determination with the aid of D F stations.

In later models of the A-4 more accurate bearing control was obtained by the use of the VIKTORIA LEITSTROHLGERÄT. He did not know the frequency nor the exact operation of this system but did state that it was a lobe switched system on the ground. On the missile were two dipoles on either side of the jet lying in a plane through the axis of the missile. The accuracy of the A-4 at 200 miles was such that 50 % fell in a square 18 Km on a side when radar was not used. With radio bearing control the accuracy in bearing was reduced to 4 Km. Their original calculations had anticipated a 4 Km square but it was never realized. The radio method was used only against Antwerp but not against London since such great accuracy was not necessary against as big a target as London. More details will be obtained from Steinhof.

Since December about 60% of all A-4's fired used Buchold's electrolytic integrating accelerometer.

N A T T E R

The following information was obtained during a discussion of the use of pilots in rockets for AA work.

A small airplane is launched vertically with a piolet in it. By means of pre-set controls similar to those in the A-4, the device is rocket propelled in a curve such that plane automatically winds up behind the bomber it is chasing. At this point the piolet takes over and maneuvers into a firing position. He then fires his 24,3.7cm rockets in one burst. To release himself he presses another button and the plane falls into parts such that he is automatically ejected and parachutes to earth.

Gen. Dornberger claimed this device was improperly designed and as a result was unstable in launching. It had a tendency to more from a vertical launching position to an upside down horizontal position which was fatal to the pilot.

Garmisch-Partenkirchen May 21 1945

Short Interview with General Dornberger.

Interrogator: Dr. F. Zwicky CIOS 183

On the"Taifun" rocket work was done by Dr.von Holt at the W A S A G.

Dr. Scheuflin (who is not available) was the inventor at Peenemünde. Interrogate Dipl.Ing. Dannenberg, who is here, on the Taifun.

Taifun at Peenemünde was done with liquid propellants (optoline and mixed acid and powder charge gas generator for pressurization). At WASAG the same rocket was made with solid propellant charge.

It was intended to fire 45 rockets from a rack. (Similar to the Russian Katusha of General Rostinko).

Bomb was not guided. Length 230 cm, diameter 10 cm, warhead 500 grams. Duration of burning 4 seconds.

General (Dr. H.C.) Walter Dornberger.

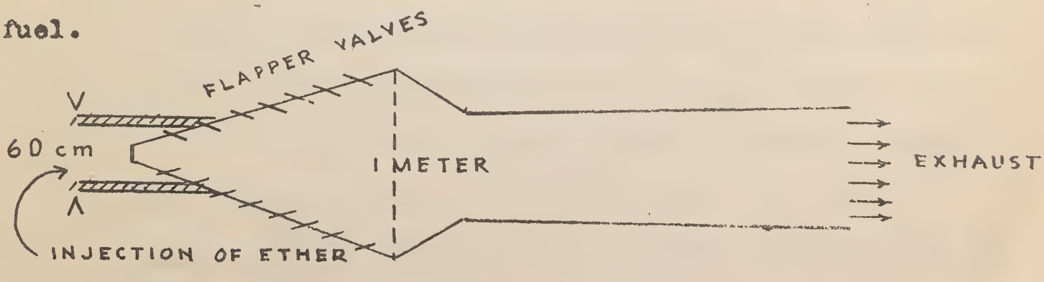
(Since January 1945 in charge of all the stations at Peenemunde)

1. The general was first asked to invite his men, down to the position of section leaders, to write a curriculum vitae in accordance with instructions given, which included details of both personal and professional careers.

2. Intermittent Duct Motors (Aeroresonators).

Dornberger's section at Peenemunde was not apparently involved in the development of resonating duct motors, but from indirect contacts, he has some knowledge of the history of these developments, as follows:

a. Dr. Paul Schmidt (Mechanical Engineer) whom Dornberger knows personally started work on the aeroresonator in 1928 in Munich (on the Flugplatz Wiesenfeld). He, at that time, had already made proposals to the Waffenamt of the Reichswehr. Schmidt experimented with a tube as shown as the fuel.



According to General Dornberger, Schmidt is the typical inventor type who has a hard time to carry out his inventions in all bitter details. He only succeeded in getting his tube to resonate for about one minute at a time, after which the combustion sputtered and got choked. The experiments were negative for a long time as far as practical applications are concerned, and they were very costly. From 1928 until 1934, the Heereswaffenamt and the Flugwaffe shared the costs while after 1938, the Luftwaffe subsidized the whole of Schmidt's developments. In 1942, Schmidt was requested to turn his results and patents for development of practical motors over to the "Argus" firm in Berlin, because he could not finance the production of his device.

b. Dornberger does not know, who, at the Argus Company simplified the injection system and streamlined the final model of the buzz bomb motor.

c. Oberstabsingenieur Bree should be able to give information on the development of the buzz bomb motor.

d. Dornberger has not heard of the work of Sanger on valveless aeroducts (Lorin tubes).

e. The buzz bomb motor was flown on piloted planes (He 111) in 1942, with either two tubes mounted symmetrically on the wings or with one motor. On the test stands, Dornberger has seen only the buzz bomb motors of regular dimensions. There were, however, two versions of the buzz bomb. The first model had a theoretical range of 250 km with a warhead of 970 kg, while the second model which was fired from Hollaud (and one of which apparently landed in Bristol) had a theoretical range of 370 km at a sacrifice of 220 kg in the warhead. (Warhead of this model was 750 kg)

f. Dornberger thought that only Argus made buzz bomb motors. However, he suggests that Mr. Sborowski at BMW who worked on the propulsive power plants for the Schmetterling and the Enzian should also be questioned.

g. Solid (powder propellants) for longer durations.

1. Diglykolpulver, manufactured by Wasag (Westfahlische Anhaltische Sprengstoff A.G.) Dynamit A.G., vormals A. Nobel (Krummel bei Hamburg) and Otto Wolff (Walsrode bei Luneburg).

2. Einheitspulver, manufactured or developed by the aforementioned factories. (Dornberger did not know that both powders gave exhaust flames and were smoky. The Germans apparently have no solid propellant without flame and without smoke. General Dornberger thinks, incorrectly, that such a solid propellant, non-smoky and without exhaust flame, is not possible).

All of the propellants were moulded with a star-like cylindrical hole through their length (and were lateral burning). The temperature range for safe firing is from minus forty degrees Centigrade to Plus sixty degrees, which range was necessary for the safe operation of assisted take-off motors in Russia. The specific fuel consumption for assisted take-off propellants is always of the order of 5-6 gr/kg/sec. while for short duration, artillery rockets, it is more like 4-5 gr/kg/sec.

Concerning the whole solid propellant development, Dr. Popl was stated to be Dornberger's best informed man. Dr. Popl is at the present at either Bad Tolz or at Koshel, Wasserbauversuchsanstalt (which is an "Ausweichstelle").

h. According to Dornberger, Hitler wanted to stop the V-2 development in 1939 and even in 1943 claimed that it could never fly because he had dreamt that it could not. The V-2 had no priority of any kind (keine Dringliachkeitsstufe). Dornberger in 1939 went to von Brauchitsch who put at his disposal 4000 soldiers with whom he built a large part of the Peenemunde stations. (Minister Speer also supported Dornberger while Tadt was against him). Dornberger says Udet committed suicide because of having ordered large series of airplane motors which proved to be no good and for which he had to take the blame.

i. At the bombing of Peenemunde August 16 to 18, 1943, the living quarters were mostly destroyed. There were 732 dead altogether, among them the best fuel chemist Dr. Thiel. Of these 732, only 120 were of the regular German staff while the rest consisted of Russians, Poles, etc. Although 1,500,000 kg of bombs were dropped, the test stations were undamaged because all of them were double floor, double roof construction and only the upper structures were destroyed. Later followed four bombings by the American Air Force of which the results were as follows:

First attack	2 dead	and	3 injured
Second "	0 dead		0 injured
Third "	0 dead		0 injured
Fourth "	0 dead		0 injured

The overall damage to the installations was so insignificant that the work went on almost to the end of the war.

j. In January 1944, the SS stepped in and, for the sake of greater efficiency, combined the stations at Peenemunde of the Army and the Air Force. Dornberger was then put in overall charge, in January 1945. Under his jurisdiction at that time came Fliegeroberst Stabsingenieur Bree who was from the FLE (Flugzeugentwicklung) and who had worked on the Hs 293, 298, Fritz X, X4, etc. Also Oberslieutnant Halder (of Flak E, Flugabwehrkanonenentwicklung who had worked on the anti-aircraft rockets came under Dornberger's jurisdiction). Dornberger relates how impossible it was in peace time several years before the war to interest any private concerns in the rocket work. He approached at that time, Siemens, Krupp, and others who would have none of it. The military took it up half heartedly, but later when Peenemunde was successful, even the Verkehrsministerium and the Postministerium became very interested for peace time publication. Peenemunde was started in August 1936. The first V-2 flew successfully along its course on 3 October 1942, indicating its position by radio.

k. About nuclear reactions, Dornberger has heard little. He thinks, however, that nothing essential has been found, otherwise, he thinks he would have been informed. Professor Werner Heisenberg was, however, scheduled to report to him quite recently on the progress in that line, but the report was never made before the collapse of Germany. Dornberger says that Heisenberg has a little house in Kochl at the Kochlsee and that he might still be there.

Dornberger confirms that all war technical projects in Germany were kept secret and very little information was exchanged between the various groups in conformity with the

Order #1

It is considered improbable that anyone should know of any further work accomplished unless it was in his specifically assigned duties.

Altogether, 3600 V-2's were shot over to England, plus 1500 test shots along the Baltic Coast and in Poland.

Interviewed 16 May 1945.

Interrogation of General Dr. Dornberger, of E.W Peenemünde, now at Garmisch-Partenkirchen, on 29 June 1945.

Present: F/Lt. H.M. Stokes, Capt. W.N. Ismay, of CIOS Team 183 and Air Defense Division, SHAEF, respectively.

Object of Interrogation.

Primarily, to obtain information necessary to assess the risks to life involved in Operation "Backfire". During the interrogation, Dornberger revealed that it was usual, especially towards the final stages, to fire the rockets within four days of final assembly, and that the proportion of failures increased rapidly with the time of storage. e.g. 4% failures after four days; 17% failures after 6 to 8 weeks. The reasons for the increase in the number of failures is being investigated by Dr. Liebhafsky and F/Lt. Stokes and will be reported in a separate paper.

Appended, is a list of 30 people, now held at Garmisch-Partenkirchen, who would be qualified to take part in the various stages of firing procedure.

(A) FUELS

1. Storage.

(a) Alcohol: Precautions as for storage of petrol.
(B) Liquid Oxygen:
  (1) To be stored at a safe distance from alcohol.
  (2) Not to be stored in closed rooms.
  (3) Not to be stored near open fires.
  (4) To be stored in meticulously clean containers free of organic matter.
  (5) Containers to be properly vented.

(c) Hydrogen Peroxide (TStoff): Precaution, as for storage of liquid oxygen.
(d) Permanganate Solution (CStoff): No particular precautions.

2. Transport

The precautions to be observed during transport are identical with those for storage, providing that the approved transport containers are used. None of the substances is particularly sensitive to shock or vibration.

In rail transport, the oxygen wagon must be separated from the alcohol and peroxide wagons by at least three "safe" wagons. It is preferable for the alcohol and peroxide wagons also to be separated in a similar manner.

If a live warhead is involved in a fire, it may explode due to the heat in one incident, a warhead exploded five hours after the incident ocurred.

3. Filling the Rocket.

(a) Provided the approved equipment is used, no particular technical precautions are necessary.

(b) Asbestos suits should be worn when handling luquid oxygen.

(c) "Mipolam" (Resin impregnated fabric) clothing and protective goggles should be worn when handling Hydrogen Peroxide. Oxidisable material must not be worn.

(d) No protective clothing is necessary when handling Permanganate solutions.

(e) All open flames are to be avoided during the filling operation.

4. Accidents with Fuels

(1) In opening a joint, an operator sustained the well-known "Cold-burns", when a large amount of liquid oxygen poured over his hands.

(2) After an appreciable stay in oxygen-rich surroundings, the clothing may become so impregnated that combustion may occur even half an hour after exposure if the operator is in proximity to open flames. Operators have been injured through smoking a short time after leaving the oxygen source.

(3) With T Stoff (Hydrogen Peroxide), the precautions observed with liquid oxygen apply to a greater degree. Organic material must not be allowed to come into contact with T Stoff. Accidents with T Stoff were almost completely avoided by observance of the necessary precautions.

5. Accidents in Filling the Rocket.

If the prescribed regulations are observed, and trained personnel are used, there are no risks. If otherwise, the risks cannot be estimated.

(B) FIRING

1. Choice of Firing Site.

(1) There are no particular limitations on the type of ground. Gently undulating, over-grown ground is particularly good from both the survey and foundation aspects. If the firing platform cannot be mounted on firm ground, a concrete or railway-sleeper, bed-plate should be constructed. Fire fighting equipment must be available.

(2) A sketch of a typical firing site is attached.

2. Mounting of the Firing Platform.

(1) The platform should be mounted on a firm base

(2) There should be no clearance between the blast deflector plate and the ground, otherwise the vacuum produced under the plate may remove soil etc, and cause the platform to topple over.

3. Condition of the Site after Firing.

(1) The area directly affected by the blast is shown in the attached sketch. Stones etc, may be thrown to distances up to 200 metres.

(2) Hollows were formed by firings from sandy ground. Firings from hard ground produced very little effect apart from slight disturbance of the surface and singeing of trees in the vicinity.

(3) The firing platform is rarely blown away by the blast; the maximum distance recorded was 20 metres. The lubricating greases etc, for the ball bearings are, of course, melted and washed away. If the platform in properly maintained, i.e., cleared and lubricated between each round, up to 25 rounds may be fired from a single platform. Without correct maintenance, the platform may only last for three rounds.

4. <u>Accidents and Failures during Firing.</u>

Failures may be divided into two categories; failure of the control mechanism and failure of rocket motor.

(1) Failure of the Rocket Motor.

(a) When using the T and C Stoff igniter, explosions in the combustion chamber have ocurred due to non-uniform ignition at the burner cups. Explosions in the combustion chamber may also occur through the presence of foreign bodies, oil etc, in the burner cups and inlet pipes.

Explosions in the combustion chamber are not usually dangerous to personnel although fragments may be thrown up to 200 metres. After an explosion, the Fueld supply is cut-off, but the fueld between the valve and the combustion chamber will drain off and feed a fire, but this can be extinguished by injecting water into the chamber.

(b) In cases where the thrust ceases after the rocket has risin about one metre, EE one round usually topples over the the fuels mix slowly causing a fire over an area of then to twenty metres radius. The fire may burn for five hours if it is not attacked by a fire-fighting unit.

(c) In cases where the thrust ceases after the rocket has risin 5 metres or more, there is usually an explosion dure to rapid mixing of the fuels. Such an explosion results in fragments being thrown up to 200 metres.

(2) If the turning programme does not operate, the rocket continues in vertical flight and subsequently returns to earth. Vertical firings were carried out from an island 1 km long and 100 metres wide off Peenemunde. None of the rounds fell on the island; the nearest was 1 km and the furthest 8 km. There is of course, no guarantee as to where rounds may fall, but the danger zone used by the Experimental Establishment at Peenemunde is shown inthe attached Sketch-

Considerable damge may be caused by an inert round falling to earth after rising vertically e.g. craters formed in hard ground will be approx. 16 metres deep and 20 metres in diameter; in soft ground, 10 metres deep and 30 metres in diameter.

CAUSES OF V-2 FAILURES

In connection with the investigation by Capt. Ismay into the hazards associated with V-2 launchings (see his attached report), General Dornberger revealed that it had proved necessary to fire V-2's as soon as possble after assembly if a large proportion of failures was to be avoided. Firing was to be within 3 days after assembly; when this was done, only 4% failures were encountered. If on the other hand, the assembled rocket was stored for 2 months, there were 17% failures even <u>after</u> careful tests and replacement of all parts found defective. We accordingly interviewed Dipl. Ing. Chem Gerhard Heller and Ing. Helmut Zoike concerning the causes of these failures. Heller was chief chemist at Peenemünde and Zoike studied failures of valves.

Both men substantiated General Dornberger's story. Failures did decrease markedly when time between assembly and firing was reduced, but no scientific study of the causes fo failure could be made in the field. Zoike estimates that of the failu es, 30% were due to plugging of the burner nozzles, 40% to valve faulures, and 30% were due to EXMEXXMEXEXX difficulties with electrical equipment.

Apparently the proportion (say 20%) of failures encountered upon the operational introduction of V-2 was unexpectedly high. An experiment was done some 2 years ago at Peenemünde in which a rocket complete without warhead and a combustion chamber were stored and examined monthly; the conclusion then was that corrosion was no great hazard, and this conclustion was borne out by examination of the parts after dissection. The discrepancy between this conclusion and subsequent operational experience is believed due to conditions being more favorable to corrosion at the front. Obviously an investigation in the laboratory of all the corossion conditions encountered in practice would be most complex.

<u>Corrosion of Iron.</u> It was established that rust from the cooling envelope plugged burner nozzles (0.8 to 1mmdia.) It was considered impractical to seal off this envelope. Dipping in an oil-water emulsion (a red oil called Standoplast) was adopted as a preventive measure. This proved successful as regards corrosion, but it introduced the following new difficulty. Upon standing, the oil coalesced and gathered at various places to cause occasional oil-oxygen explosions when liquid oxygen flow was started.

<u>Corrosion of Aluminum.</u> The formation of aluminum oxide "sprouts" was observed expecially on castings such as those in the pumps. Some XXXX general corrosion of the aluminum was also to be expected. All these aluminum corrosion products could contribute to the plugging of the burner nozzles. In addition, aluminum showed intergranular corrosion at the welds, of which there was a great number. Welding often caused grain growth; atmospheric corrosion of the grain boundaries subsequently weakened the metal; when

the metal was subsequently strained as in the filling of the alcohol tank, rupture occurred and the alcohol leaked through. Beads of the alcohol were occasionally seen to form in this way; a special inspection of the rear of the rocket was always made before firing to see whether such leaks were present.

The presence of alcohol where it was not wanted often gave rise to oxygen-alcohol explosions. Such explosions are one explanation for the "Luft-Zerleger".

Anodic processes for producing protective films on the aluminum were contemplated but were never applied owing to the size of the job. A green organic lacquer was applied to the aluminum surfaces before the welding, and the welds were repainted afterward.

No penetration of the 1.5 to 2 mm. Aluminum walls was ever observed at a distance from a weld.

Clogging of Burners. When the nozzles of burners were clogged, as by corrosion products, the burners usually showed heat damage. Such damage occurred more often with the alcohol nozzles, but the oxygen nozzles also suffered. The explanation advanced was that the plugging upset the oxygen-alcohol ratio in the neighborhood of the nozzle affected, and that this would lead to unduly high temperatures in the neighborhood.

Failure of Valves. Valves could fail because of corrosion. For example, corrosion products could jam magnets so as to make them immovable, thus making magnetic valves inoperable. Although chrome plating was resorted to for protecting steel parts, the plate often failed to protect, which is not surprising in view of the diffuculty of the plating job; in one case for example, the walls of a hole 4 mm wide and 20 mm. deep had to be plated.

Valves often failed because rubber (or ersatz) gaskets seized. Sometimes rubber (or ersatz) parts became brittle. Rubber bonded to metal often separated from it, which caused leaks.

Electrical Difficulties. The V-2 had a multitude of places (contacts, soldered connections, clamp connections) at which corrosion could produce circuit difficulties. Failure at one of these could cause failure of the rocket. Deterioration of rectifiers and of other electrical devices occurred on storage. Much of the electrical apparatus contained ersatz materials. Hydraulic oil occasionally thickened.

Because of these many potential sources of trouble, a careful check-up as complete as possible was always made of the electrical system before a rocket was launched. Even such a test often failed of its object because circuits that passed a static test successfully ran into trouble owing to vibration incidental to the launching and flight of the rocket.

Ignition. Two methods of ignition, pyrotechnic and chemical (TC) were in common use, the latter being more popular at the front. Each has its drawbacks, and no final decision as to relative merit has yet been possible.

The pyrotechnic method consists of a rotating (Catherine)wheel driven by the emitted jets of fire. The resin framework used was supposed to be completely consumed. Nevertheless, chunks of resin carried along by the rocket jet often damaged the carbon vanes, and this difficulty was serious enough to warrant the introduction of another ignition method.

In the TC method, T-Stoff (hydrogen peroxide) and C-Stoff (hydrazine hydrate,presumably with a catalyst) are mixed, whereupon an almost immediate flame results. The chief drawback of the method was the complexity of the mechanical system, which led to frequent failures. These failures, unlike those of the preceding paragraph, in no way damaged the rocket; it was only necessary to replace the defective ignition unit with a good one.

Recommendations for Firing. Zoike and Heller recommend that all captured rockets be carefully tested before firing, and that all defective parts be replaced. They suggest mechanical cleaning to remove corrosion products. They point out that disassembling, cleaning and reassembling, if too thorough may introduce more troubles than they cure.

The testing falls into three main catagories; (1) electrical testing, including testing of the controls (2) low-pressure leak-test of the entire assembly above the pump; the high pressure side below the pump cannot be leak-tested.

Combustion tests cannot be made on the assembled rocket. Motors can be removed from the rocket for static tests.

V-2 was always fired with the tanks full, the oxygen tank being topped up after wailts of more than 20 minutes. With full tanks, the initial acceleration was one g. The rocket will stand accelerations up to 4 or 4 1/2 g. Obviously, starting with the tanks nearly empty would damge the rocket. Gen. Dornberger considers firing with reduced loads possible but too risky to attempt.

Conclusion General Dornberger expressed the opinion that not more than one out of 20 or 30 captured rockets could be launched sudcessfully in their present condition. Zoike, perhaps less pessimistic, thought we might expect 25% failures on captured rockets carefully tested, with parts replaced where necessary. In any case, careful testing by trained (German) personnel would seem to be in order before launching is attempted.

We believe that the German experience with V-2, as described herein, deserves careful consideration in connection with any attempt to fire the captured rockets.

H.A.Liebhafsky & H.M Stokes (CIOS 183)

Garmisch-Partenkirchen, 30 June 1945

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INTERROGATION OF DR. Wilhelm ELFERS

BY: F/Lt. Stokes, Dr. Porter at Garmisch- Partenkirchen.
DATED : 21 May 1945.

Dr. Elfers was primarily concerned with the stability of the control equipment of the "Wasserfall", and with the " Einlink-Rechner". He worked under Dr. Netzer, both at Peenemünde and at Neve Bleicherode and was to a certain extent responsible for Dr David's work on the electrical model. See report (which is separate) for details.

By placing together the various ideas obtained from Dr. Elfers, and others a schematic diagram of the ground control equipment intended for Wasserfall was drawn. This diagram, shown in Fig. 1., is believed by the interviewers to be essentially the system planned for Wasserfall. It should be realized that no system of this kind has actually been tested and there was a certain amount of disorganization amoung the various individuals working on the developmen as to what would be satisfactory and what would not.

Two radar systems of the "Mannheim" type are used for determining the present position ofthe target and of the rocket, respectively. Because radar units cannot be located close together, a parallax comput is used to convert the data from one of the systems to the coordinate system of the other.

For the first six seconds of flight, therocket rises vertically under its own control. At the end of this time the operator takes control and flies the rocket in accordance with information presented on an indicator (cathode-ray tube). This information includes the difference in azimuth or angle preferably the slant-plane angle between the rocket and the target, which is presented on the horizontal plates, and the difference in elevation angle, which is presented on the vertical plates, thus moving a spot in such a way as to indicate the angular position of the rocket with respect to the line of sight.

During the transition period, when the rocket is to be guided from its vertical path into the line of sight, a second spot is shown on the indicator, which gives an artificial elevation position for the rocket, displaced from the real position by an amount equal to the displacement of a theoretical transition path from the line of sight. Thus it is only necessary for the operator to keep this second spot in the center of the tube in order to guide the rocket smoothly into the required trajectory.

The displacement of the second spot is computed by a device known as the "Einlink-Rechner", sometimes referred to as "Gummiband". It contains two integrators which are arranged in a feed-back system so as to produce the second derivative of the elevation angle between the rocket and the target. The difference angle is brought to zero as quickly as possible , by "Gummiband" without exceeding certain arbitrary values of the acceleration.

A third computing element known as the" T- Rechner" is also required for this control system. As can bex seen in Fig 1, the motion of the rocket is controlled by a "joy-stick" which changes the keying of four audio tones on the transmitter " Kraň", one pin of tones corresponding to motion of each pair of control surfaces. However the rocket is not fired from a rotating platform and consequently the relation between the control suffaces and the vertical will depend on the azimuth angle of the target. Furthurmore the relation of the control surfaces tothe x vertical will change during flight depending on the exact nature of the trajectory, as shown in Fig. 2. It is true that the arrangement of the gyroscopes in the rocket is such as to prevent rotation about the axis of the rocket, but the type of motion shown in Fig. 2 does not include rotation about the axis and consequently can occur. The "T" computer keeps track of the position of the contol surfaces and resolves the motion of the control stick in such a way as to send the proper signal to each pair. This resoloing action can be accomplished in several ways, the simplest siply being a rotation of the whole control-stick assembly with respect to the operator.

The A 4 "Mischgerät" was used but had to be changed because of the different roll stabilization. All four rudders are used for roll correction instead of only two as in the A 4. The same kind of stabilization R-C network was used in Wasserfall as in A-4. Thirty-five rockets were fired using the K-12 Servo and five using the new electriacal Servo. Of these last five only one worked as it should. Position feed-back was used from the rudder.

Dr. Elfus was asked about testing the stability of a rocket system, and gave a brief description of Dr. Davids model. He believes that Davids electrical device is very much better than Dr. Hausserman's pendulum foraccurate work.

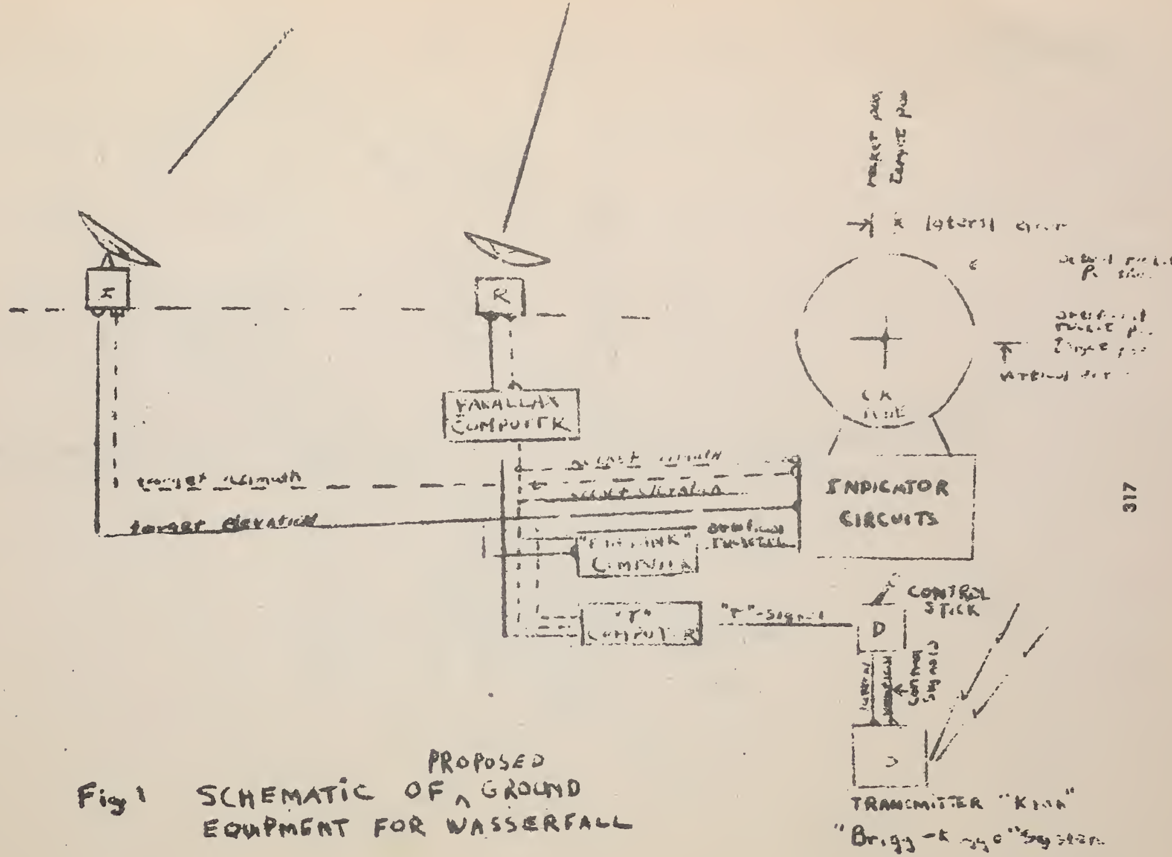


Fig 1 SCHEMATIC OF PROPOSED GROUND EQUIPMENT FOR WASSERFALL

21 May

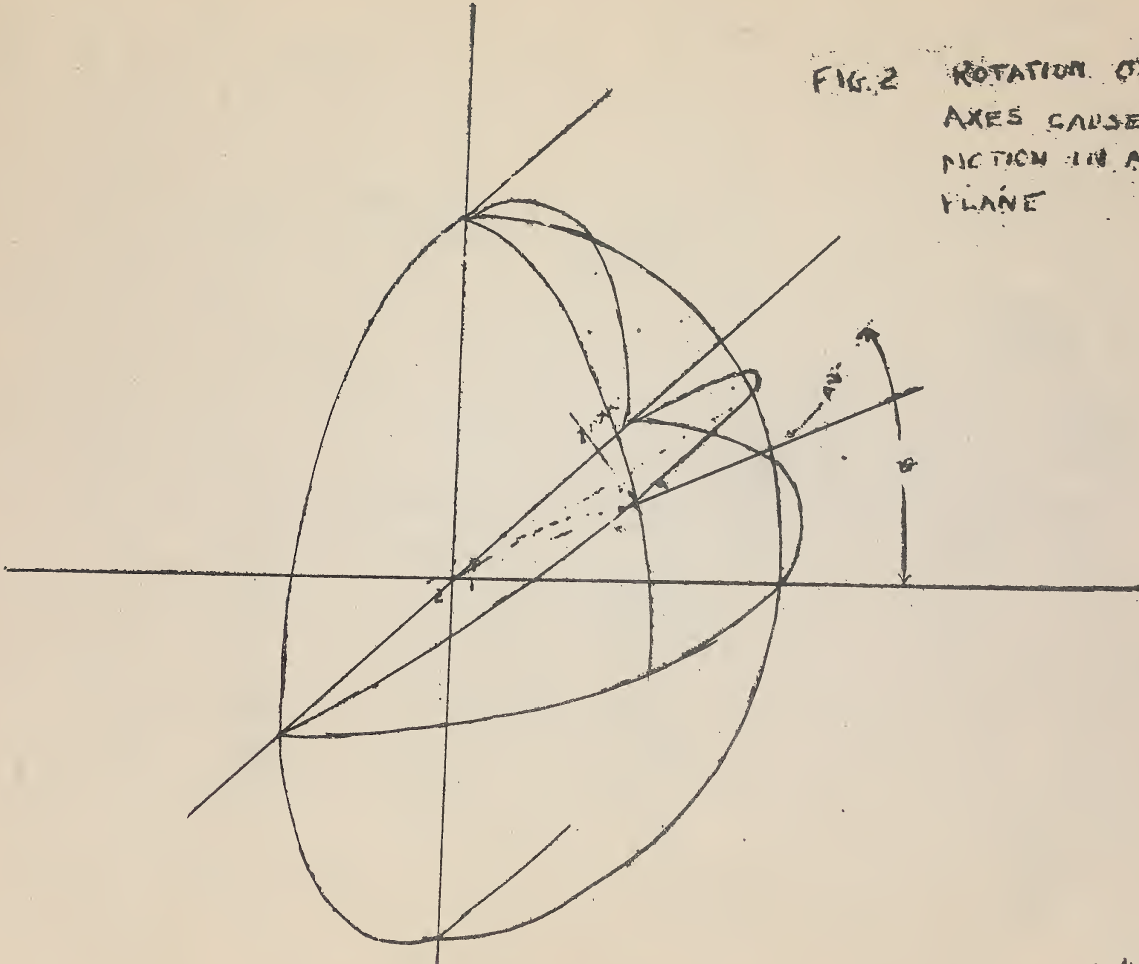


FIG. 2 ROTATION OF CONTROL AXES CAUSED BY LATERAL MOTION IN A SLANT PLANE

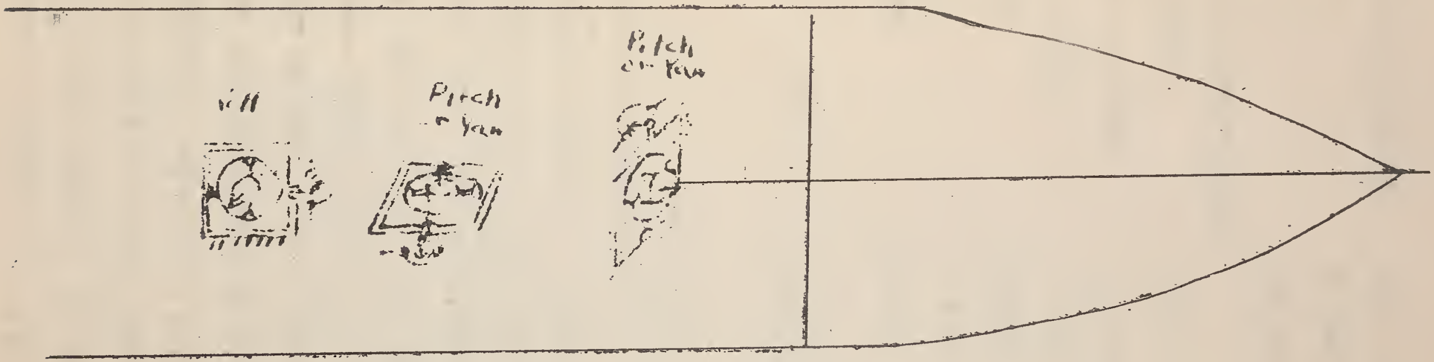


Fig 3. Arrangement of Gyroscopes
in Wasserfall

21 May, 19[illegible]

1. Personal details and this man's career are given in an earlier report dated 15 May 1945

2. The following details were obtained regarding the "Rheintochter" which is a two stage anti-aircraft rocket. Dr. Fricke stressed the point that he could give only approximate dimensions etc. so the figures should be checked from other sources. There were three models of the "Rheintochter" which are referred to as I, II, and III. Dr. Fricke could give us no information regarding III. The information on I and II is tabulated below. Both types I and II were radio controlled (Strasburg-Kehl) and some 60 types of I, and 3 or 4 of types II were made for tests. samples of III were made.

Details of "Rheintochter"

	I	II
Length	450 cm (not more than 500 cm)	350 cm
Diameter	50 cm	50 cm
Weight	1.6 ton	1.3 - 1.6 ton
Payload	100-150 Kg	100-150 Kg
Total Impulse	[illegible],000 Kg Sec	100,000 Kg. sec.
Angle of Launch	30° - 80°	30° - 80°
Max. Height	6,000 m (Approx)	14,000 m. (Approx)
Time of burning-stage 1	1.2 Sec	1.2 sec.
stage 2	10 sec.	40 sec
Velocity at launch	30 - 50 m/sec	30 - 50 m/sec

Acceleration at launch	50g (?)	50g
Fuel - Stage 1	solid propellant	solid propellant
Stage 2	" "	solid or liquid
Length of projector rails	2 meters (?)	2 meters
Fuse		Radio proximity. No homing device was contemplated.

3. Dr. Fricke was questioned regarding the nature of the solid propellants but he could give no details. He said that this was a matter for the manufactures and referred us to the L.S. Dept. of Rheinmetall-Borsig (Di Ing. Muller). He stated that he did not know the pressure in the combustion chambers but said that the walls were 8-10 mm thick.

Interrogation of Dipl Ing Geissler - EW 22 and Dipl Ing Johann Klein EW 22, re Wasserfall. Present S/L Sharp and F/L HW Stokes.

1. Geissler confirmed that the differences between the four Wasserfall types resided mainly in the dimensions and form of the rudders and the design of the "Heck" or rear section of the missile, also the steering mechanism.

2. The steering mechanism used were as follows:

W 1 — Askania servo gear as used in the A-4
W 2 — Not known
W 3 — K 12
W 4 — Two types of servo devices were projected for this:

(a) An hydraulic mechanism termed "Primitive Hydraulik" specially designed by LGW for use in Wasserfall. This has a limiting factor of 70 secs in which time the hydraulic content is used up. The pressure is derived from a nitrogen bottle especially fitted for this purpose. According to Geissler, the pressure of the N-bottle is 60 atm and this reduced to 30 atm for operation.

(b) At Peenemünde, work was in progress on air Electric servo chanism by Geissler, Klein and Niklas. This was still very far from completed, work was still in progress. This was substantially confirmed by Dipl Ing Johann Klein.

Both subjects confirmed that Wasserfall was far from a state of completion and that basically the state of the weapon could be called fully developed as far as the missile itself was concerned, whereas the control problems had only been partly solved. No single trial against a target has so far been made.

WASSERFALL

Thees.
Team 364

Control System - - Dr, Klein, Dr. Geissler

Wasserfall, at least in the earlier models had three free gyros mounted so as to measure pitch, yam and roll separately. Each had a doublé potentiometer pick off on the outer ring. wired as a bridge circuit so that a movement of the outer ring with respect to the case unbalanced the bridge. The latter was fed with D.C. so that a D.C. output was obtained from the pick off. This D.C. output was fed into a ring modulator which produced a proportional 500 c/s AC output. This was then amplified rectified and fed to the rudder servos. There were four separate rudders servos which each drove a linked aerodynamic and jet rudder assembly. The servos used were the LGW oil type as used in the later models of U2. A pure electrical servo of smaller size had been designed and was to replace the oil servo. The output from the pitch gyro came from the ring modulator as a balanced output and this was fed to the two amplifier valves operating the two horizontal rudder servos. The output of these valves was so arranged that a balanced out put worked the two rudders in the same direction, and so produced pitch. In the same manner a balanced output from the valves operating the vertical rudders moved them in the same direction and gave yam. The balanced roll output was fed to the centre points of the balanced pitch and yam putputs. This caused an opposite motion of the horizontal and vertical rudders and produced roll. A potentiometer in the rudder servo provided a feed-back signal which was fed back into the ring modulat r inputs. For a given gyro insalignmment and therefore the rudders took up a given deflection ß given by $ß = K\alpha$ - - The motion of the rudders in taking up this deflection by internal servo damping being damped. The constant k was determined both by calculation from wind tunnel measurements and by trial in test flights, in order to obtain self-stability of the missile. It was varied as a function of time by altering the potential applied to the gyro pickoff. In this way stability was maintained as the speed varied. Radio control was by means of the standard Kehl - Strasbourg gerät as used in HS 293. The system used CW on 49.5 infs modulated with two pairs of tones, one for L/R and one for U/D. The output from either command channel wa s an equal space to mark square wave when no command was being given, a command giving an increase o decrease in the space to mark ratio, so that the mean DC level of the square wave was proportional to the amount of control stick motion. The command information was fed back into the stabilizing circuit in either of two ways. In one way the receiver output was fed through a relay amplifier called the "Ita-regler" to a small DC motor which then rotated the gyro fick-off potentiometer at speed proportioned to the mean DC level of the command signal.

When this method was used, therefore, the change of direction of flight was proportional to the time integral of the amount of control stick movement away from neutral postion. In the second case the receiver output was rectified and the resulting D.C. signal was fed into the appropriate ring modulator in series with the gyro putput. This then produced a change of flight direction proportional to the stick motion, and on returning the stick to its neutral position the missile flew again in the original direction. Apparently the rate method of control was preferred.

The receiver aerial system consisted of two crossed dipoles, each element of which was mounted on an insulating support on the trailing edges of an air rudder.

METHOD TO TRAJECTORY CONTROL

The weapon was, in the first instance for use in daytime against day bombers and an optical method of control was to be used. The setup on the ground consisted of a firing platform, a telescope for observing the target, a telescope for observing the missile, the observer for this telescope being in control of the missile, a computer called the "Einlenk Gerat" and the Kehl transmitter. In the set-up at Peenemunde these various postions were grouped together within a few metres of one another.

The missile was controlled so as to fly on a line of sight course with respect to the controlling observer and the target. The method of launching the Wasserfall however vecessitated some increased complexity over the simple line of sight procedure. The missile was launched vertically and flew in this direction for six seconds up to a height of 150 metres. It was then necessary to control the missile so that its direction as seen by the controlling observer was the same as that of the target. If theses directions are defined in terms of elevation and azimuth the method may be described as follows. Apart from parallex corrections, the observers telescope started by looking vertically. After six seconds, its azimuth was controlled by the aircraft viewing telescope so that the two were equal. Its elevation was also controlled so that if target elevation was γ and the observers telescope elevation was β we have the differential equation: $f(t)\ddot{b} + k(j-\dot{b}) + g(j-b) = 0$

K is a calculated damping constant. f (t) is a function of time after launch such that: $f(t) = \frac{12}{t-5}$ t in secs. and g (γ - b) is function of the elevation insalignments which is approximately linear for small insalignments but becomes constant at large values. If the controlling observer kept the inside central on the crossed wires in his field of view then it flew on a course which approached the correct line of sight asymptotically and when it was actually on the line of sight he held it there as closely as possible. A difficulty arose since the control axes of the missile did not coincide with the control axis of the observer.

The relative rotation of the two systems arose because the missile could be directed on to any azimuth, and since it could not roll about its own longitudinal axis a roll with respect to space axes was produced. This effect was to be measured with some form of radio gear on the back of the projectile. Since roll is to be determined, some form of polaritation method was necessary, the 180° ambiguity being resolved by a knowledge of the control applied. The component of roll with respect to the line of sight was then fed into the control system, as for example by rotating the control stick pick-off column, so that the observers axes became those of the missile. The whole correcting device was called the "Tau-rechner". For use when visibility was not good enough for optical control radio methods had been thought about. The use of the Wurtyburg equipment for target position measurement, assisted by Doppler effect methods to overcome the use of window was considered, the idea being to use, the azimuth and elevation from this set for feeding into the Einlent gerat. A second Wurtyburg was used for the missile positioning, the aerial being rotated manually so as to move the control line in accordance with the Einlent gerat output and the missile misalignment with respect to this aerial being kept at zero by the control stick operator. The initial control from the vertical position into the Wurtyburg beam was by optical methods, by observing the ilumination from the jet through a telescope.

HOMING - Dr. Weiss

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

$$B = f(E)$$

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

The homing device consisted of a mirror with a rotating shutter at the focus. The light passing through the shutter was fiffused on to the surface of an Elac infra red cell, the output of which was amplified. Weiss produced a shutter with stips giving square wave chopping of the radiation, the chopping being at constant frequency for an image on the axis, but having an increasing frequency modulation deviation for a source at increasing angular misalignments. The output of the amplifier was therefore connedted to a frequency discriminator giving a vine wave output whose amplitude was a linear function of radial unsalignment and whose phase, on comparison with a reference commutator gave insaligment components with respect to the eye axes. The use of frequency modulation as an measure of proportional unsalignment was said to give the direction of the brightest spot in a distributed target rather than the centre of gravity ofthe radiation, but this does not appear to be true if normal amplitude limitting is carried out before passing the signal into the discrimminator. This method however seems to lead to a very simple circuit for sorting out proportional insaligment. The beam width necessary for a homing device used in this manner was determined by the accuracy of the "Kräke Gerät" and also how far the manoverability of the missile could keep E=0. Beam widths actually used were from 6° to 12°. Weiss said he had a scheme for using a much narrower beam but refused to discuss it. It is presumed that he was considering a locked follow eye with initial scanning in order to find the target.

<u>The Einlenk Gerät</u> - Dr. Elven

The Einlenk gerät was for solving the equation

f

The circuit was as follows:-

The values of g B and gγ are obtained from non-linear potentiometers n the missile and target telescope axes. was obtained from a generator on the target telescope axis.

We have from the equation (1)

$$\ddot{\beta} = - \frac{K\dot{\gamma} + K\beta + g\beta - g\gamma}{f(t)} \quad (2)$$

$$\text{ie } \dot{\beta} = \int \left[- \frac{K\dot{\gamma} + K\dot{\beta} + g\beta - g\gamma}{f(t)} \right] dt \quad (3)$$

The terms - $-K\dot{\gamma}, g(\gamma - \beta)$, with $f(t)$ fed in as over-all amplitude control, were integrated, with feed back of $K\dot{\beta}$ and the resulting output was $\dot{\beta}$. This was again integrated and the output β was used to drive the observers telescope servo.

<u>The Taurechner</u> - <u>Dr. Lange</u>.

One method proposed by Dr. Lange but not actually constructed was to follow the target with a scanning Wurtyburg beam and to have a responder in the missile. Since the polarization of the Wuryburg beam was rotating the signal picked up ~~byxxxx~~ had a dipole on the missile / sine / modulation. The phase of this modulation with respect to the totation of the Wurtyburg dipole gave the required angle of roll, Tau. The signal picked up by the missile was repeated ~~xx xxx~~ back tothe ground where it was received, and the second harmonic compent was picked upt. This was used to lock an oscillator of frequency equal to the rotation frequency of the dipole and the output of this was compared in a phase sensitive rectifier with a sine wave generated on the dipole shaft itself. To avoid ambiguity it is necessary that a continuous measurement of Tau be made.

<u>Proximity Fuses</u> - Dipl. Ing. Smück

Proximity fuses for Wasserfall were being developed by several firms. Electrical P.F's were:-

Marabou - made by Siemens-Halske- Berlin.

This had Tx and Rx with separate aerials. It worked on a frequency of 375 Mc/s and the transmitter had a saw-tooth frequency of deviation several Mc/s with a 1 kc/s repetition rate. There was also an amplitude modulation of 100 kc/s. Signals reflected from a target were picked up by the receiver and mixed with some of the transmitter signal. This produced in the mixer a 100 kc/s signalwith an amplitude modulation of frequency equal to the difference of frequenxy between direct and reflected signals.

After passing through d 100 kc/s filter this was rectified and the result was passe into a furthar filter which could be set to pass signals below a certain valwe, depending on the range at which the fuse was to operate. Switching in the last stage was by means of a dynation circuit last filter had a rising frequency characteristic up to the cut off point so that within the pass band the sensitivity of the device was approximately constant.Its max. range was 50-60 m.

The 100 kc/s mod provides sefurity against jamming.

kakadou — made by Donag. Wien

This device was similar to Marabon in that it used separate TX and RX, but it had no frequency modulation and worked by means of the Doppler effect. The TX frequency was 300 M/Cs. This device also had the 100 kc/s modulation for security.

Kugel blitz. Made by Patent-Werkungs Gessellshaft-Salzsburg

This was a simple system consisting of a TX/RX working into a simgle erial. Its method of operation can be envisaged either from the Doppler effect or from impedance changes. Its sensitivity was such that impedence changes caused by rudder movements or by ribrations of the missile skin could give false operation of the fuse and so its use for Wasserfall was not seriously considered.

Fox - made by A.E.G. and Triditer made by Blau-Prinkl worked on the same principle as Kugelblitz.

Optical P-F's were

Wassermans - made at the Research institute at Kochel.

This consisted of a light source which was used to feed a system of rotating lenses. These projected light beams in a forward direction. Reflected light from a target was received by a photocell from a limited forward field of view and apmlified in a 3-stage amplifier tuned to the scanning frequency of the light beams. This provided a safeguard against interference from constant light backgrounds

Paplity - made by Elac at Kiel

This device consisted of a lead sulphide cell having a forward looking cone of view with a central stop. Radiation from the target was received by a cell, and its intensity increased up to the point of the eclipse by the stop, when it fell rapidly. This rapid fall off was used to detonate the missile.

Some work on P.F.'s was also done by Dr. Brinkmann at the Reichpost Forschungs Anstelle. His device consisted of a combination of photocell and infra-red cell arranged so that a decoy which would give light as well as heat radiation did not operate the fuse.

Garmisch-Partenkirchen, May 20, 1945.

INTERVIEW WITH DIPL. ING. ERNST GEISSLER.

Was concerned with aerodynamics and the control of "Wasserfall" since 1943. The aerodynamic data were supplied by the wind tunnel people.

Requirements for "Wasserfall"

At first a firing range of 20 km in height and 50 km horizontal distance was projected. Requirements were reduced to 15 and 30 km respectively. Maximum target plane velocity of 250 m/sec was assumed. Acceleration of target was assumed 2 g: Maximum acceleration taken into account was 10 g (Lastvielfaches 10). Final shape of Wasserfall was however never established.

"Wasserfall" was the first missile of its kind.

The aerodynamic form of this missile was shaped from experiences gained on the A4.

Geissler analyzed the aerodynamic requirements and the stress analysis, then characteristics of the rudders, etc. Electrical and hydraulic controls activated by batteries were used, but Wasserfall controls were never finished.

In tests the missiles were fired and directed with radio controls for the purpose of testing:

1. the aerodynamic stability of flight and the controlability of the path.

2. to test the performance of the jet motors during the flight.

3. to test the rudders and control surfaces.

A great number of difficulties were encountered which at the war's end had not yet been eliminated.

Maximum velocity reached was 600 m/sec. (Projected 700 m/sec and the flight through the transonic region was pretty well mastered).

Also tested during the flight were the gyros, the vacuum tube installation, jet motor feed system, etc.

The infra-red homing device with a sufficiently large field of view (several degrees could not home at more than 3 km distance).

The first main method was to direct the missiles electrically from the ground. Missile was released vertically and through telescopic observation electrically directed straight towards the missile. This change of direction was accomplished in a very definite previously theoretically described manner. The release from the electric steering and the transition to the optical homing was in the development stage. (Theoretische und Labormassige Regeltechnik).

All control problems were first tested on laboratory models.

INTERROGATION OF DIPL. ING. GEISSLER. 13 June 1945.

Smith & Wilkinson
Garmisch.

Geissler was interrogated for the purpose of completing the information in regard to the tie-in equipment between the homing head of the automatic target-seeking device and the control surfaces. His work in this respect has been chiefly theoretical. The fundamental problem consists of utilizing the error information from the output of the homing device and, in the simplest approach, converting this information to the form $a\varepsilon + b\frac{d\varepsilon}{dt}$. Actually, for the problem in three dimensions, the error will appear in the form of two componets, $\varepsilon 1$ and $\varepsilon 2$, which must be operated on separately and transferred to the proper control surfaces. In an actual projectile the"own stability" of the projectile must be combined with this information in order that theprojectile will be able to fly a stable course. Figure 1 indicates the schematic arrangement of the combination of the two essential factors: epsilon, the error information, and phi, the stability information. As shown in the diagram, the outputs of the two similar computing devices R_{ε} and R_{phi} are additively combined and transferred to the input of an amplifier which operates the control surfaces.

The error information obtained from the homing head consists of two components which may appear in the form of polar or Cartesian coordinates. If the information is in the form of Cartesian coordinates it is applied direstly to the computer. If in the form of polar coordinates it must be converted by some device to Cartesian coordinates. Also the angular information of the relative position of the projectile frame to the gyros must be obtained in the form of Cartesian coordinates phi_1 and phi_2. These two sets of information, which appear as DC voltages of variable amplitude and either polarity, are fed to the computingdevice. Each component, $\varepsilon_1, \varepsilon_2, phi_1, phi_2$, is treated independently in the computor and by circuits similar to figure 2 is converted to the corresponding form:

φ_1 To $A_1 phi_1 + B_1 \dot{phi}_1$

φ_2 To $A_2 phi_2 + B_2 \dot{phi}_2$

ε_1 To $a_1 \varepsilon_1 + b_1 \dot{\varepsilon}_1$

ε_2 To $a_2 \varepsilon_2 + b_2 \dot{\varepsilon}_2$

These components were to be added electrically as per figure 1 to yield the following:

$$A_1\varphi_1 + B_1\dot{\varphi}_1 + a_1\varepsilon_1 + b_1\dot{\varepsilon}_1$$

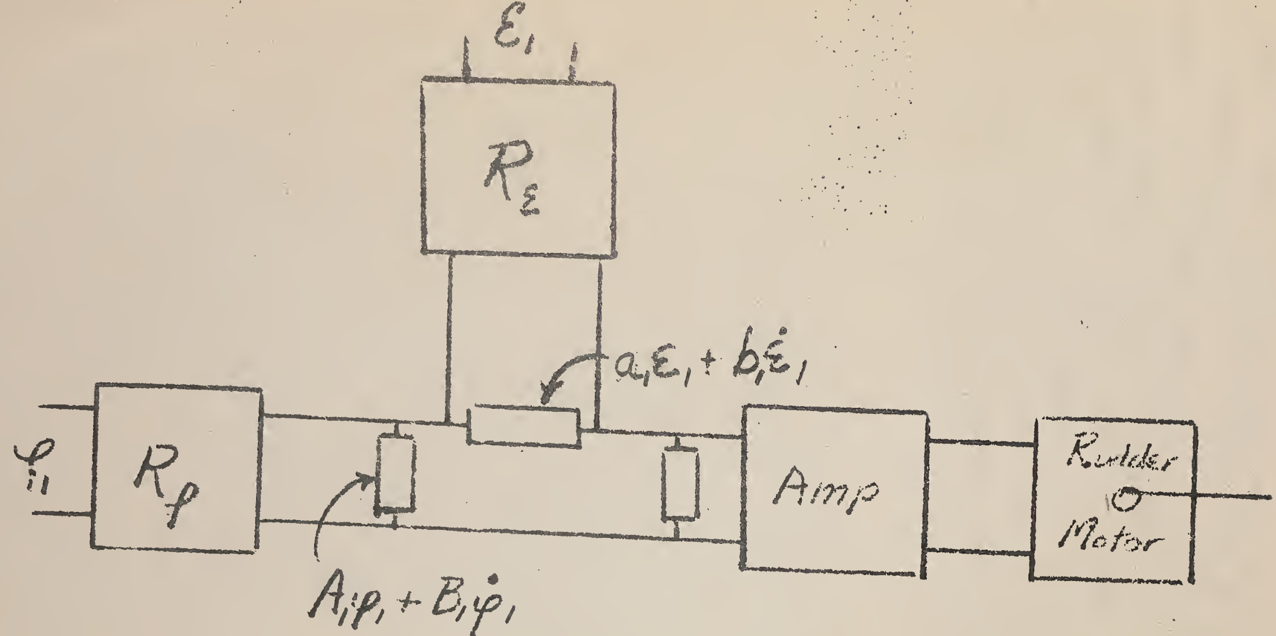
and

$$A_2\varphi_2 + B_2\dot{\varphi}_2 + a_2\varepsilon_2 + b_2\dot{\varepsilon}_2$$

The electrical sum of each set of components is fed into an amplifier the output of which operates the corresponding control surface. It must be stated here that this particular arrangement was never assembled wherein both homing system and "own stability"were conjunctively used, A-4 used the "own stability", or phi portion, alone. Both magnetic amplifier and vacuum tube amplifier were considered, but no definite decision was made. It was hoped that a megnetic amplifier would be possible.

More detailed information of the two-gyro system of Krücke B described in the previous report of Dr. Weiss (11 June 45)(and 12) was obtained and is as follows: Figure 3 shows diagrammatically the stabilized platform in the missile whose perpendicular is always directed toward the target, and the arrangement of the two gyros. A similar arrangement is provided on the ground, where the platform follows exactly the postion of the target-tracking radar. When theplatform is moved, gyro pick-offs Pyy and Pxx measure the angle through which the platform has been moved. This information is trans~~ferred~~ mitted by radio and applied to motors My and Mx. For the sake of simplicity the action of gyro Gy only will be considered. The action of Gx is similar. Motor My exerts a torque on the gyro axis yy-yy. This causes the gyro Gy toprecess about the axis yx-yx. Pick-off Pyx in turn drives the motor My to turn the platform relative to the missile to a new position compatible with the information received by the radio link. Actually the gyro does not appreciably change the position of its spin axis in space. The perpendicular to the platform, which is identiaal with the axis of the homing head, does, move tothe new position,directed toward the target, as called for by the information transmitted from the ground. When the missile has come within range of the target so that the homing device can take over, the axis of the homing head will thus point very nearly in the direction of the target, and the radio information to motors My and Mx ceases. Very soon thereafter the target will not be exactly in the center of the homing device, and error voltages will exist which are fed to the motors My and M_X

Thus the platform is driven to a new position with respect to the missile frame and pick-offs P_y and P_x may be used to steer the missile through the computer. It will be noted that in this system the axis of the hominghead was not rigidly fixed in space. However, the same type of constant bearing course results as in the previos system described in the report of Dr. Weiss. In this case the gyros maintain the fixed reference in space and, after the correction has been made by the change in flight path of the missile, the axis of the hominghead again returns to the same direction with reference to the gyro orientation.



Similar arrangement for φ_2 and ε_2

Fig. 1

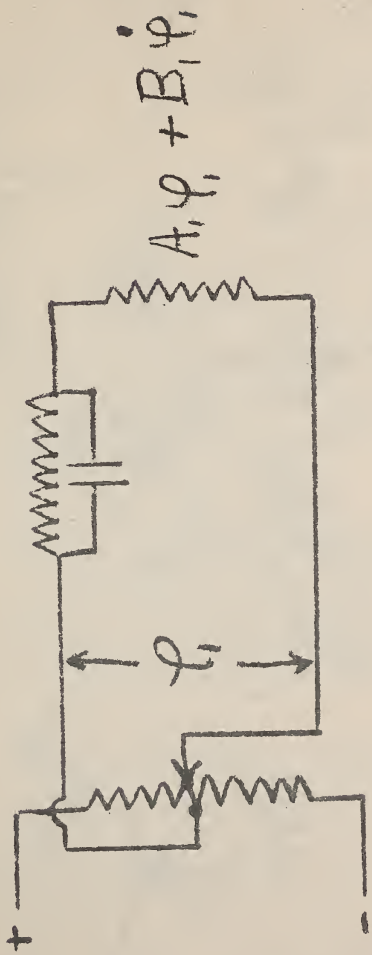


Fig 2

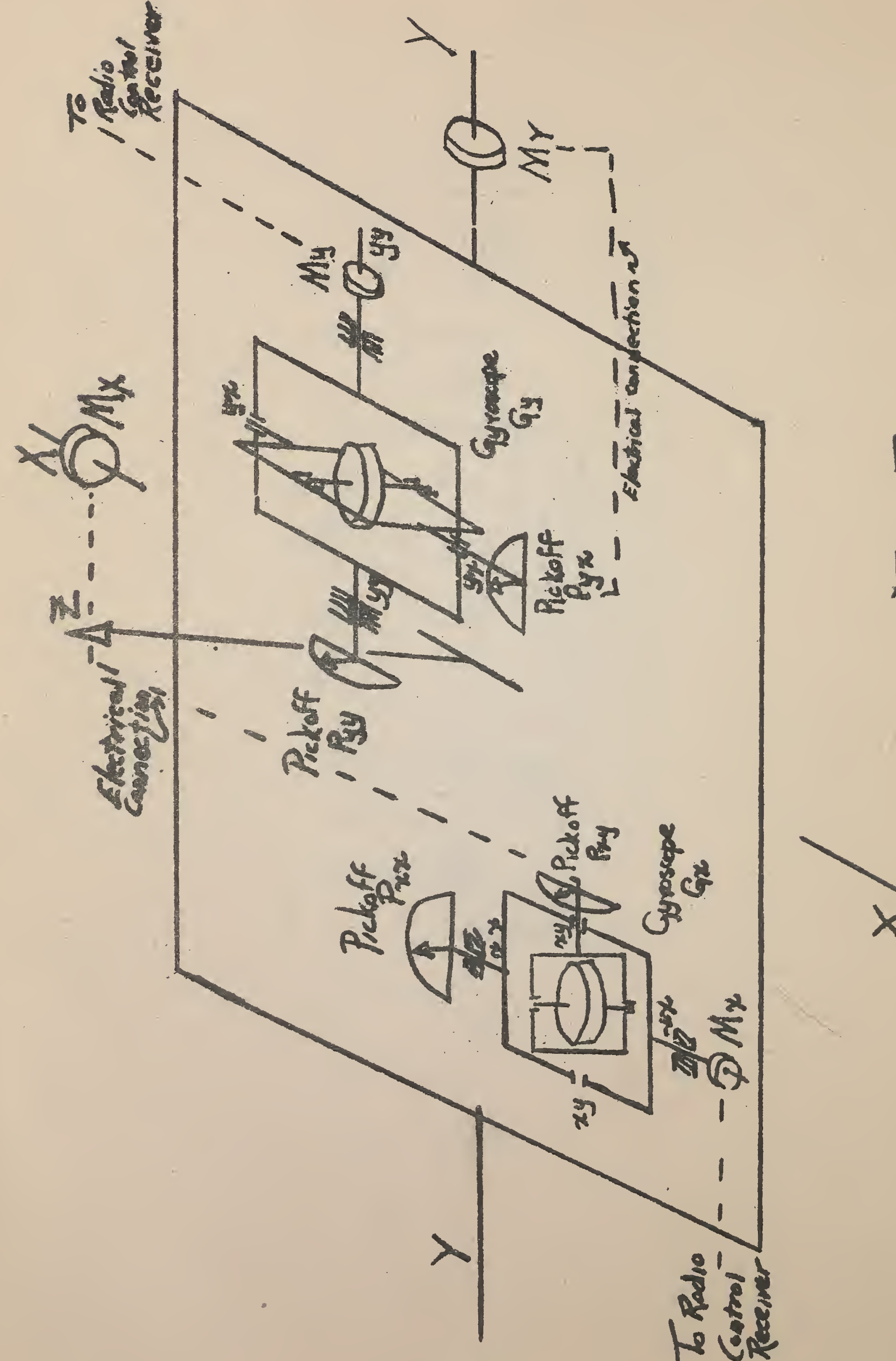

To Radio Control Receiver
Electrical Connection
Pickoff
Gyroscope Gy
Gyroscope Gx
Pickoff
Mx
My
X
Y
Z
Electrical Connection
To Radio Control Receiver

FIG 3

INTERROGATION OF DR. Ernest Geissler - 25 May 1945.

By F/Lt. Stokes, Dr. Porter at Partenkirchen

Dr. Geissler was asked certain specific questions about the control system of Wasserfall and gave the following information:

1. The gyro arrangement shown in the report on Dr. Elfers is probably incorrect. Dr. Geissler thinks the plan was to use the x arrangement in Fig 1 of this report. (A more logical arrangement in our opinion).

2. Our idea that the direction of flight of the missile is controlled by rotating the stators of the gyroscope by pick-off potentiometers was confirmed. This rotation is accomplished by means of a small motor which runs at a speed proportional to the magnitude of the control signal. Stabilization of the local system consisting of gyroscopes, amplifiers, rudder servomechanism and rudder, together withthe feed-back through the movement of the missile iscalled an " Eigendampfung", and is accomplished by known methods of feed back and anticipation. Intellegune is fed in to this system in the manner described above, whether it be from ground control or from a homing device. Stability of the over-all system must be studied in each case and appropriate measures taken, i.e. the rate term in the control signal mentioned by Dr. David,

3. A new system using rate gyroscopes was being studied theoretically for use in Wasserfall. Twotypes of amplifiers consiered, namely a magnetic ampfifier, and a relay amplifier. The magnetic device was considered most likely to be used, but it had certain disadvantages, not the least ofwhich was the fact it might not be available from the manufacturer. The relay system was considered in some ways limited by the availability of gyroscopes with pick-off devices having sufficiently strong current aapacity.

4. For homing control a system was planned which is known as the parallel-line or constant-bearing system. It makes use of a flexibly mounted infra-red (or radar) homing device called a "Zielsuchkopf", Which can be made topoint in a constant direction with respect to fixed co-ordinates by means of three gyroscopes and appropriate servo mechanisms. The operation of such a system is illustrated by Fig 2. The first and mostdifficult problem is to bring the rather narrow field of the homing device to bear on the target. This can be accomplished in either of two ways: (a) by transmitting the angular position of the line of sight(x) to the rocket by radio and measuring it off, by means of the servo motors, with respect to a fixed coordinate system maintained by gyroscopes, or (b) by using a radio set on the rocket to D/F on the transmitter of the Mannheim, thereby establishing the correct direction with respect to the rocket.

Once the target is in its field the direction of the homing device is held constant with respect to fixed axes, and the output or error signal is applied to the steering control of the missile. As a result the missile is brought into a collision course, the angularity of which depends on the speed of the missile, and the speed of the target. If the speed of the target and of the missile are both constant, and the target flies a straight path, then the path of the missilewill also be straight, otherwise it willbe curved but collision will still occur. R.W.Porter

Garmisch-Partenkirchen, May 21, 1945

Interview with Mr. Heinz Geise, Dipl.Ing.

Interrogator : Dr F. Zwicky CIOS 183.

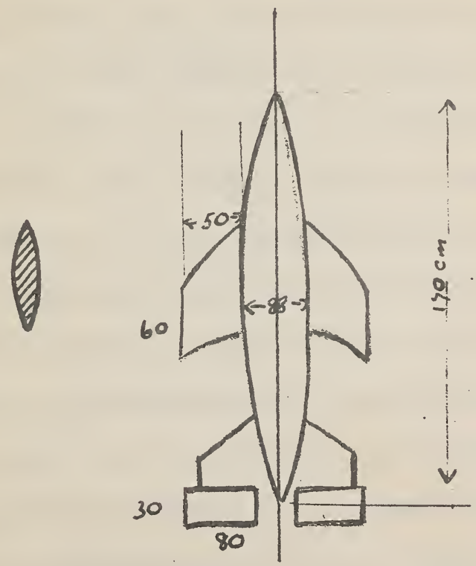
Built the combustion chamber and the injection system for the Wasserfall propulsive unit of 8 tons thrust. For the inner casing St 52 R (Reichsbahn material) was used while the outer casing St . 12 (Ordinary steel sheet).
Production : Pressing of two longitudinal half sections and then weled. Exhaust nozzle and chamber are one unit. Flexure joints near the nozzle. Flexure joint was connected with a reinforcement ring.

During the runs it was possible to stand within about 20 meters with the 8 tons jet motor.

Hellebrand, Emil.

Hellebrand was born August_1944 and was educated at High School and the Technical High School in Darmstadt. He is a Diploma Engineer and was a soldier from 1939 to January 1940 when he was discharged.

Hellebrand worked at Peenemunde on calculation of Wasserfall stresses from 1940 onward.



Thrust 8 ton. Stabilizing fins about same size as the wings. Acid tank - manganese steel. Graphite blades in jet.

Interviewed 21 May 1945

Emil Hellebrand, Engineer.   18 May 1945

I was born on August 1, 1914 in Vienna. The son of Dr. Phil Emil Hellebrand, the chief professor of the High school for soil-culture. After four years of grade school and eight years of high school, from 1932 to 1934 I attended the Technical High School in Vienna. In 1934 I attended the Technical High School in Darmstadt. In 1938 I took the final examination as construction Engineer.

My special work was engineering design. Immediately after my schooling, I became scientific assistant to Prof. Dr. Eng. Emil Kammer in Darmstatd for statics of building construction and later assistant to Prof Dr. Kurt Kloepple for statics and steel building.

I had two months of Military training in 1937, two months in 1938 and three week in 1939. I later went into the army as Acting Corporal, and until January 1940 I was a Soldier.

On January 30, 1940 after I was discharged from the army, I worked at the Army Ordnance Testing Institute at Peenemunde as a co-worker in the Projector Department under Engineer Roth.

I also worked on the problems of airplane statics and design, performance calculations and air mechanics in the preliminary stages. For the last two years I was the group leader of statics and designer in the project department.

In March 1940 I got married. My wife and three children are living at present in Steinbruecken by Nordhausen in Harz.

Signed: Emil Hellebrand

Dr. Ing. Friedrich Wilhelm Bornscheuer. May 17, 1948

I was born on May 2, 1917, as the second child of six. My father is Pastor Wilhelm Bornscheuer. My mother, Emmi Charlotte, maiden name, Berner, Guttersbach, Odenwald. I am a Protestant. After 3 years of public school I went to grammar school at Schotten, Oberhessen. I received further education at the Classical Grammar School in Mainz, until Spring 1935. After 6 months labour service, I studied building engineering. From Winter 1935/36 till Summer 1939, at the Technical High School in Darmstadt. Stood my pre-exam. in the Fall 1937, and the main exam. in the Fall of 1939 and passed both with "very good". From October 16, 1939 until I was drafted into the Army (September 1940), I was first assistant to the professorial chair for Statics, Steel Bridges and other Steel Constructions above ground at the Engineering Laboratories, High School at Darmstadt. On January 1, 1940, I was promoted to the position of director-engineer at the Engineering Laboratories of Dr. Ing. Kloppel. At this time I was mainly concerned to accomplish static-tests on the larger parts of steel and aircraft construction. In connection with this, I performed theoretical and experimental work in the rudiments of steel construction. During several furloughs from the Army, I had an opportunity to carry out further work under the direction of Prof. Kloppel, mainly theoretical treatises on the higher elastic sciences. In my treatise of the 31 March 1944, which I submitted for my degree of Doctor of Engineering and passed with distinction, I dealt with the problem of the swelling of even, reinforced plates under a pressure load.

May 1, 1942, I was sent to Peenemunde, as legal representative of the Electro Mechanical Works GMBH, Karlshagen, where I had been employed as "Chief Statician" since early Summer 1942. My main duty was to draw up a static loading plan for the apparatus A-4. This was done in close cooperation with the air mechanical and aero-dynamical experts. Late Summer 1943, I took the leadership in the newly formed static-test-group whose problem was to calculate a "static foundation", for the carrying conduct of the entire "apparatus parts" and the "part load" construction. All implements worked over by the "E.W." were inspected. This was done in close cooperation with the department for material inspection as well as with the experimental shops. In the preparation and evaluation of the experiments, I was assisted by Dipl. Ing. Schack II and Dipl. Ing. Wingensiefen. Since the installation of the experiment-static department in Karlshagen became too small for the continually increasing demands, the great installation of the "Institute for Firmness of the German Experimental Station for Air Travel" (DVL) at Berlin-Adlershof was rented in the Fall 1944 to conduct large scale experiments. At the end of January 1945, we had 14 engineers and numerous other professionals and craftsmen working on static experiments. We also used the Engineering Laboratories of the Technical High School at Darmstadt since early Summer 1942 for static experiments. Co-worker of Prof. Kloppel was in particular, Dr. Ing. Cornelius.

December 16, 1944, I was married to Miss Elizabeth Margareta Thauer, from Mainz. Student of domestic-science.

Signed: Bornscheuer.

RESTRICTED

INTERROGATION OF DR. HORN at Partenkirchen, 21 May 1945

By F/Lt. H.M. Stokes
Dr. R.W. Porter

Dr. Horn is a former student of Dr. Vieweg's at the Darmstadt T.H. His principal problems at Peenemünde were the design of the graphite rudders and the manufacturing problems connected with the Kreiselgeräte integrating gyro, code name "Iller-gerät".

The biggest trouble with the graphite rudders was that of breakage. Usually they broke at the point of attachment to the metal base. The XXX troubles were overcome by use of a liberally rounded fillet and by proper placement of the bolts which hold it in place. The graphite blocks were obtained from Firma Siemens-Planier, and was known as "Sondergvalitat".

A similar but smaller graphite rudder was also used on Wasserfall. Many test were made to determine the XXXXXXX optimum shape. Finally it was decided to use an almost rectangular shape, with the forward end swept back at an angle of 15 or 20°, corners rounded.

Dr. Horn reviewed the terminology for the various integration devices

"I" is general, refers to all types.

"I-1" or "Iller" is the gyroscopic device designed and built by Kreiselgeräte.

"I-2" or "Isar" means the original device of Prof. Buchhold with a integrating cell.

"I-3" or "INN" designates the more complicated system using two measuring devices and a stabilized platform.

The "Iller" was first and for that reason used the most. Towardd the end, however, Isar was beginning to be used quite a lot. Inn was never actually used so far as Dr. Horn knew, but was planned. The "Stabipla" was not a stabilized platform used with "Inn" as we had supposed, but was simply the name for the base on which the various gyroscopes were mounted.

Dr. Horn was given responsibility for the Iller only, and XXX didnt know much about the others. He siad hoverver, that the Isar, for reasons not entirely understood, did not give performance as good as had been expected, and that he believed the Iller was simpler and better.

The principal troubles with the Iller were frictional errors, bad ball bearings, non-uniformity of parts, and so on. However, errors of more than 1% in measurement were not likely to accur in practice, and in the laboratory 0.1% could be obtained.

He had heard others mention "Querintegration" and "Shubreglung" projects, but knew nothing about them. The A-5 he had seen "as an object" but knew nothing more. The A 7 (A5 with wings) and the A9 (A4 with wings he had never even seen).

R.W. Porter

Dr. Gerhardt Heller. — Propellants

"Visol" is the designation (Tarnname) for Vinylether

$$C_2H_5\text{-O-Ch} = CH_2$$

Visol propellants were mainly chosen because they can easily be made spontaneously ignitable with red fuming nitric acid. (In the V-2, photocells were used to trigger the initiation of the main propellant flow.) Heller was propellant chemist and thermodynamicist. The thermochemical performance calculations were mainly done by his collaborator, Dr. Buchner. Heller originally made some of the exact performance calculations, taking into account the minor propellants, with Prof. Wagner in Darmstadt. The water-gas equilibrium in all calculations was assumed to be frozen in at 1800°K during the expansion.

$$H_2O + CO = H_2 + CO_2$$

The equations of flow taking into account the running equilibrium of the combustion products were integrated graphically but the charts are lost for the present. In the V-2, the following propellant combination was adopted

-(75% C_2H_5OH + 25% H_2O) + liquid oxygen

Propellant ration used:

0,8 kg 1 kg

while the stoichiometric ratio is

0.64 kg to 1 kg

The theoretical exhaust velocity (at 15 atu) is 2275 m/sec.

2. (The "Elektromechanische Werke at Peenemunde with Dornberger in charge originally was run by the army but was ultimately transformed into a private concern). Heller was in charge of a group of 16 chemists and laboratory assistants who worked on the performance of new propellant combinations. About half of them worked on the development of "hypergol" (spontaneously ignitable) propellant combinations for jet motors intended to propel anti aircraft missiles.

3. Spontaneity of ignition was tested with the droplet-cup test method. The general rule was that if the ignition time was smaller than 5 to 10/1000 of a second, then the mixture would ignite safely in a jet motor without the danger of explosions by delayed ignition after the combustion chamber got partly filled with unreacted propellants. The shortest ignition time found for any combination was about 2.5/1000 seconds. To insure that the oxygen of the air did not falsify the validity of the tests some checks were run in an atmosphere of nitrogen.

4. With mixed acid (10% of H_2SO_4 in nitric acid) the ignition time with various fuels proved to be almost independent of temperature over a wide range.

The following "hypergol" combinations were run. One part of pure nitric acid + 0.23 parts of "Visol" which theoretically should give about uex = 2100 m/sec.

Mixed acid + "Visol"

in stoichiometric proportion. Theoretical uex = 2000 m/sec.

5. Originally, the "Flakgerate" were run with a combination of Diesel oil + nitric acid. In order to get rid of the necessity of special ignitors, the more easily ignitable Visols were introduced. "Visol" in Germany was a new product (Heller does not remember the price of it). It was generally found that complicated mixtures of various fuels were more "hypergol" towards various oxidizers than simple liquids. In particular, there always seems to exist a relative mixture ratio at which the ignitability against nitric acid takes place with a minimum retardation time. With a mixture of some aniline, the visols become spontaneously ignitable with nitric acid. Triethylamine which is very easily ignitable with nitric acid also makes the visols readily ignitable with nitric acid. For further dilution of the mixture, phenols were used especially a crude oil mixture called Optol.

6. For the standard tests of jet motors for anti-aircraft missiles, the following mixture, which is called "Optolin", was finally decided upon. This consists of Optol + aniline + visol + benzol + xylol, which has a density of about 0.91 as far as Heller remembers, with boiling point about 35°C, and freezing point about minus forty degrees centigrade. The requirement of low freezing point accounts also to some extent for the choice of the above complicated mixture.

Optolin + mixed acid

should give about 2000 m/sec exhaust velocity. The combustion chambers in this case were always cooled with the acid since the available flow of fuel would not be enough for cooling. (Neither Dornberger nor Heller remember any exact figures for heat transfers in either the V-2 motors or the motors of the various missiles.)

The combination of N_2O with Optolin was also tried.

For the Wasserfall missile, the tests were made in test motors of 4.2 tons thrust and on the full scale motor of 8 tons thrust.

In connection with armaturen (fittings, feed lines, valves, regulators) on acid resistant steels, acid resistant gaskets, O-rings, valve seats, etc., Mr. Millinger and perhaps Mr. Palm were suggested for questioning.

7. Mixture ratio: Optolin : mixed acid

0.23 kg : 1 kg

The combination gave a bright yellow jet very similar in appearance to a bright sodium flame. At the beginning and end of the run, thick brown clouds of nitrogen oxide etc. were exhausted.

The stoichiometric ratio for the above mixture would be about Optolin : mixed acid

0.21 kg : 1 kg

Rules for best mixture ratios. The mixture ratio is usually chosen with two points in mind.. These two points are:

(a) highest possible performance

(b) Lowest possible chamber temperature without too much loss of performance or too high precipitation of carbon.

An index to the choice of the mixture ratio is the so-called

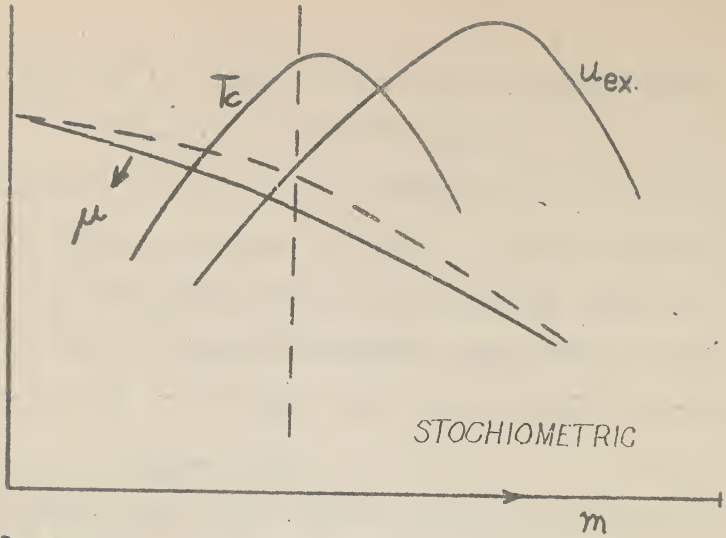
Sauerstoffuberschusszahl

which is used in the performance calculations of Otto motors. (Sauerstoffuberschusszahl = index of oxygen excess). This index number is equal to unity at the stoichiometric ratio. If the air excess or the oxygen excess relative to the stoichiometric amount of oxygen is say 20%, then A = 1.2. For instance in the case of ethanol and liquid oxygen, it is most advantageous to run with about A = 0.8. For other combinations, the optimum value of A is somewhat different and for combinations like $2H_2+O_2$ the optimum A is quite different from the above. These results follow from considerations on jet performance which have been made in a very similar manner by investigators in many countries. One plots the expression for the exhaust velocity

as a function of the mixture ration r = mass of fuel/mass of liquid oxygen or other oxidizers. The graphical plots for the mean molecular weight u of the combustion products, for the chamber temperature T_c and the exhaust velocity uex are as follows:

x = ratio of specific heats

Pe = exit pressure Pi = chamber pressure



8. <u>Miscellaneous.</u>

Heller confirmed the information which we got at Volkenrode that Sanger some time ago worked with emulsion and coloidal suspension of Aluminum in various organic fuels, and apparently got in as much as 50%. Sanger at that time worked in Trauen in the Luneburger Heide. Heller tried zinc diethyl as an initiator for combustions. About 50 to 100 kg a month of this air inflammable substance were produced at the "Chemisches Werk Schollene at Rathenow, Berlin. This work did not result in any practically accepted procedures. Neither was some initial work with Aluminum trimethyl continued. On the work with the H_2O_2 (80%) (produced by IG Farbenindustrie) and run with concentrated (27%) $NaMnO_4$ solution. Heller knows little but suggested a talk with the men who worked on the "steam" generation for the turbine pumps of the V-2.

9. <u>Start of the V-2.</u>

For the start of the V-2, a ground installation was used which ran on the hypergol mixture (Hydrogen peroxide + Hydrazine hydrate). The jet from this reaction was shot up through the nozzle into the combustion chamber of the V-2. A thermo-element in this chamber indicated the temperature which when it reached a prescribed value, released the main propellant flow of ethanol + liquid oxygen, which combination ignited on the hot gases already present in the chamber. Of the above auxiliary combination, about one kilogramm of propellant was shot into the main combustion chamber within 5 seconds.

Interviewed 16 May 1945

GERHARD HELLER - Dipl. Chem. (second interview)

Interviewed on 21 May 1945 by GJG and HAL

Graduated T.H. Darmstadt, spring 1940, no subsequent army experience, at HAP 11 since 1940, in charge of chemistry of fuels.

Heller prefers nitric acid to liquid oxygen as oxidant for rocket fuels; thinks highly of tetranitro methane (if available) on the basis of small scale experiments. He would be willing to use nitric acid in a very large rocket though the somewhat low specific impulse of these fuel combinations is somewhat of a deterrent. The fuel planned for A9 was 75% ethyl alcohol and liquid oxygen, the choice being dictated by past experience. The water is, of course, added to reduce the flame temperature. Heller says he can burn 95% alcohol in small but not in large chambers. Perhaps contrary to expectations, the cooling problems are more severe in large than in small chambers. Small (1 ton) chambers do not require spray cooling; large do. When chambers get too hot, they fail in a manner characteristic of the the metal used in making them. Aluminum begins to melt, and large sections of the metal are torn out. Still chambers look as though a welding torch had been run over them.

In Heller's time, no work was done at HAP 11 on gasoline and liquid oxygen. He feels that such work had been done 6 or 7 years before, and that alcohol was then chosen, though he does not know on what basis. Work on hydrogin hydrate at HAP 11 was confined to its use with hydrogen peroxide as a liquid igniter.

In 1940, a 1 ton chamber was the smallest in use a Peenemünde. In 1943, the smallest was on of 4.2 tons thrust. In the future, Heller would be willing to jump directly from chemical laboratory experiments to a 100 ton XXXXXX thrust unit, although he would prefer to operate the large unit initially at reduced thrust. Almost all testing at Peenemünde was done with the combustion chamber vertical, exhaust down, this being preferred as it is the launching position. Burners are apt to behave differently with the combustion chamber in different postions. Chambers have been tested horizontally and with the exhaust upward.

Optolin was originally compounded with availability in Germany as the overriding consideration. It has the advantage of high density. It is by no means unique. As a matter of fact, all fuels that burn well with nitric acid give about the same specific impulse. Optolin contains aniline and visol (ethyl rinyl ether) to insure ignition; optol, benzol and xylol because they are available. Optol is a coal tar distillate that contains the phenolic bodies objectionable in ordinary applications. Here, however, the phenolic bodies serve to keep the benzol in solution, which helps to make optolin stable at low temperatures. Xylols serve the same purpose.

Heller did not work with nitrous oxide or monofuels. He knows Myrol, but has not studied it. Oxygen arrives first in the A4 combustion chamber. Fuel arrives first in the Gerät Wasserfall. There were no serious explosions in the development work on the latter; the fuel burned smoothly.

H.A.L.

DISCUSSION BETWEEN C.I.O.S. (183) AND DIPLOMA ENGINEER PALM AS WELL AS DIPLOMA ENGINEER HELLER

Fuel for "Wasserfall".

Optolin and a mixture of (H_2SO_4 and HNO_3 for nitration) approximately in the stoichiometrical proportion approximate effect.

Theoretical rate of outflow --- 2100 m/sec
Actual rate of outflow -------- 1780-1800 m/sec

Demand or delivery system nitrogen high pressure sphere of 235 liters content loaded to 260 atmospheres. Rear pressure reducer 27 atmospheres.

Fuel --- Tank quantity 385 kg
Acid --- Tank quantity 1600 kg

Theoretical Burning Duration --- 45 seconds
Actual Burning Duration --------- 40-42 seconds

Acid flows through the cooler.
Temperature range in the cooler approximately 60°C.
Maximum rate of flow in the narrowest cross cut of the cooler 4m/sec.
Combustion chamber pressure 20 atmospheres.
Combustion chamber temperature theoretical 2800°K.
Maximum axel acceleration 4.5 g.
Maximum side acceleration 12 g.
Maximum mirror deflection 70°.

Tank discharging through the medium of a balanced flexible pipe. Free flow of high pressure, at the same time as the take-off of the apparatus by means of the firing valve.

The pressure reducer was not fully developed, the waste of the low pressure is about 80 atmospheres high pressure.

Theoretical value of the entire impulses 360 000 kg/sec.
Actual value of the entire impulses 320 000 kg/sec.
Entire weight of the empty apparatus 1760 kg.
Weight of the nitrogen 70 kg.

(For comparison with the A-4 nitrogen tank pressure in the gas cylinder batteries there are 200 atmospheres and the nitrogen low pressure is about 40 atmospheres).

With the waterfall, the thrust falls off at about 25 seconds and reaches a final value of about 5500 Kg.

The average molecular weight of the burning gas in the combustion chamber is Ca 26.

The average k is not exactly known, because the outflowing equation was graphically integrated.

The Question of the Hypergolity.

The visol was chosen as a basis for the fuel because it can with relative ease be made hypergolically. Under the application of disposable organic supplemental material, visol in itself is not hypergollic with nitric acid.

Firing Delay as a Function of the Proportion of the Mixture.

Insertion conditions (logistics). These conditions made the use of fluid oxygen impossible, with Waterfall and similar apparatus; demanded storage capacbilty for full tanked apparatus 1 year.

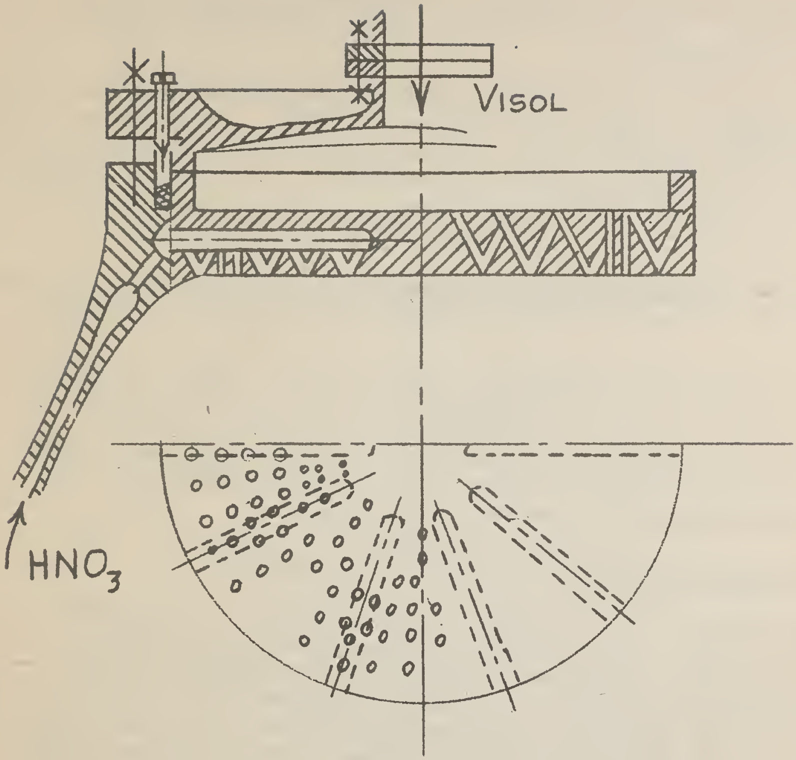
Liquid Oxygen.

Vorwerk Mitte by Lehesten in Thuringen, was the supplier of liquid oxygen. For transporting, special tank wagons were used.

Power Works and Armatures for Waterfall.

Combustion chamber is similar in form to the V-2. The cooler is straight without spiral guidance - 2 expansion joints. Volume of the combustion chamber 75 liters (IX = 100 inches). Narrow nozzle cross-cut 192 mm ∅. Cooler force 5-6 mm (Cp = 1.4). Inner combustion chamber covering out of ST 52. Outer combustion chamber covering out of ST 37 (most usually machine construction tin). The mix-nozzle (see the sketch) is a drilling mix-nozzle.

(Sketch on following page).......



Both materials will be sprayed against one another until ¼ is used up, (fuel against acid). This system has the task of assuring the performance of the firing, whereby the streams meet each other undecomposed, so that the benefit of the decomposition is imperfect. Immediately after the meeting a lively reaction is present, however, only on the direct contact surface. With the remaining ¾, the drill nozzle sprays fuel against fuel and acid against acid; this gives a good decomposition; on the other hand the ignition would be poor if both systems were not combined (compromise firing). The proportion 1/4 : 3/4 became empirically ascertained. With the variation of this proportion poor ignition or heavy oscillations in the burning process present themselves. The nozzles are made of light metal (centrifugal castings).

Pressure loss in the cooler 1½ atmospheres. Injection pressure loss on the fuel side 2 atmospheres. Injection pressure loss on the acid side 3 atmospheres.

Functioning of the apparatus previous to ignition, the firing valve is activated by means of electrical ignition. There is no restriction of the high pressure, after the bursting of the diaphragm on the gas side (a bursting pressure of 10 atmospheres). The nitrogen flows over the pressure reducer and divider into two fuel tanks. Immediately following, the air cushion in the fuel tanks is loaded with nitrogen.

Upon reaching 10 atmospheres, the diaphragm, on the liquid side, breaks, so that fuel and acid flow into the combustion chamber unhindered.

The building up of pressure in the tanks continues until the predetermined tank pressure of 25 atmospheres is r ached. The time from the firing of the firing valve, until ignition, takes about 5 seconds. The pressure rise in the combustion chamber follows (according to an exact formula). It is calculated that it takes about 4 seconds after ignition u til the full combustion chamber pressure is reached.

Pressure raisin~ in the fuel tanks by means of warming.

Upon fueling of the apparatus, the temperature of the fuel is about 8°C, corresponding to the ground temperature. With any lengthy standing of the apparatus, a most unfavorable heating of 50°C is to be reckoned with. Hereby, the fuel and acid expand considerably. The bursting pressure of the diaphragm amounts to 10 atmospheres. For safety reasons, a pressure rise of 5 atmospheres is allowed in the tanks. Correspondingly, these valves must therefore be released with the filling of the gauged air cushion. These amount to:

In the fuel container - 18 liters (tank volume 453 liters)
In the acid container - 48 liters (tank volume 1043 liters).

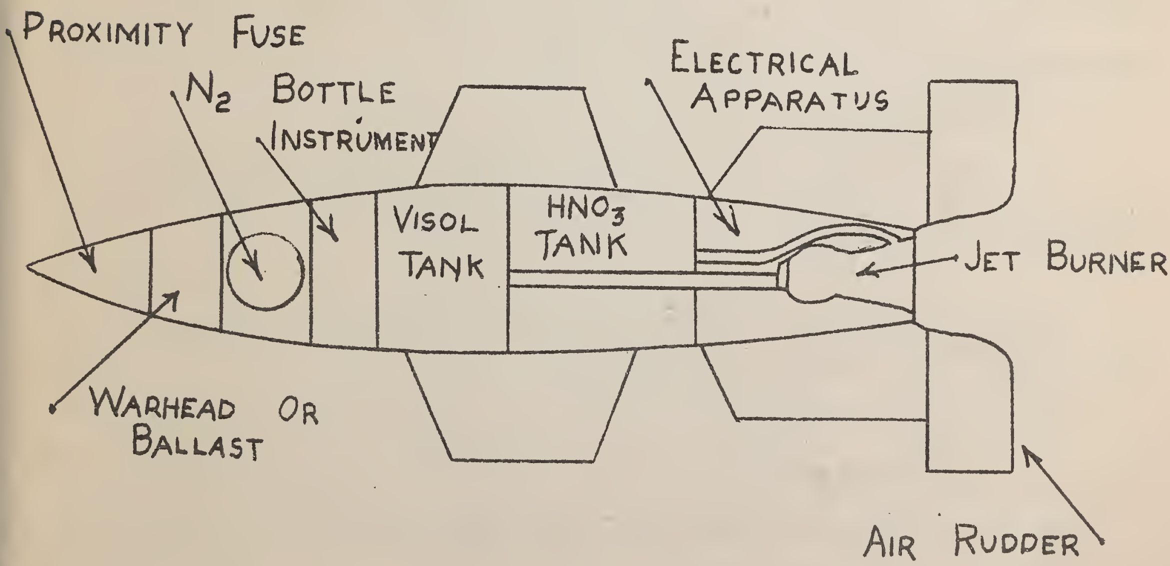
Corrosion.

As the nitric acid and mixed acid (H_2SO_4 and HNO_3) in small quantities vigorously corrode unalloyed steel, various means were looked for to correct this deficiency. On the test stands, tanks were either finished with aluminum or covered with aluminum V2A steel dress.

Piping and armature parts which came in contact with acid, were immediately finished out of V2A steel (highly allo ed) with the apparatus itself, it was not possible to use alloyed steel, for reasons of difficulty in obtaining raw material. During storage, only the acid tanks with fitted piping up to the diaphragm, were in constant contact with the acid. As an efficient protection, an acid resisting enamel was produced, which was planned for mass production ST 37, from which all the pipings were finished;

very little was attacked by the acid. It could not, however, be used for the t nks, on account of its slight firmness. (This should be finished in aviation work material 1265 or 1604). The diaphragms, which are aluminum are not in the least affected or corroded by the acid. The corrosion in the combustion chamber during the 45 second burning time is of no importance. Acid will not flow through the armatures. Otherwise, the case lays with the test stand trials, where one and the same apparatus, or one and the same combustion chamber repeatedly were burned. The acid tank of the apparatus held out for six to eight trial runs, until it was corroded through, in defiance of the water which was thrown over after the test run, with a good combustion chamber, up to twenty trial runs may be reached, with a careful flushing out.

A Sketch of the Apparatus "Wasserfall" (Waterfall)



Mensuration of Thrust.

(1) Measuring stirrup (is a V formed spring) maximum deformation 1.5 mm by 8 tons thrust accuracy plus or minus 1%. Oscillation by combustion process and too hard igniting repeatedly damages the stirrup. The experiments were exclusively made with vertically hung ovens. Self oscillation figures of the stirrup really higher than the frequence of the oven oscillation, that no resonance was present.

(2) With balancing scales, (the oven hung in a manner parallelogram). The thrust course was recorded by means of a scriber in the same manner as with the stirrup.

Remarks.

Measuring apparatus development was worked by Herr Schuler. Research program "Wasserfall". The testing of the whole power units and the fuel valve of the oven and combustion research was worked by Herr Palm.

The V-1 was tested at the Air Force Testing Grounds in Peenemunde. The plant manager was Lt. Col. Stams. The experimental Chief was Dipl. Engineer Weygand.

Different Defects.

(1) Test Stand View.

The first defects in this line were the valve defects, caused by the packing eaten up by the acid. As packing material the commercial Oppanal was used primarily, available in various grades of hardness and various thicknesses. Color : Violet.

Further valve defects were through seisure of valve slides. The valves were N2 actuated servo valves. N2 was set free through Electrical Magnet Valve (Solenoid) and actuated the main valves.

Further defects purely mechanical.

(2) Oven or Apparatus Side.

The oven repeatedly bursted by the water hammering at time of ignition.

Burning through of the oven.
Mixing jet covered with rosin on the fuel side.

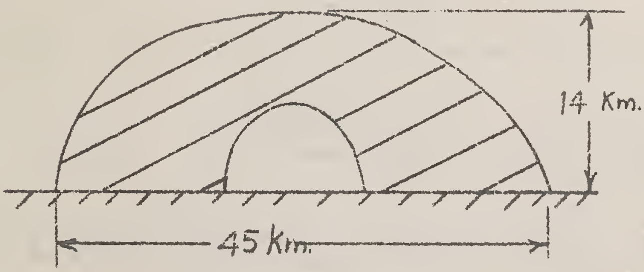
Defects in oven head: Light metal jet is broken or sprung repeatedly through hard igniting, letting the injection streams come together too soon; cause an explosion of the oven head. Furthermore, hard ignition caused jet to spring a leak in its seat.

Remarks:

The experiments were observed through small parts which were covered with unbreakable glass.

Work was done toward the improvement of the injection system with the view of raising the velocity factor from 0.85 to about 0.92 in the A-4.

The length of flame of the Waterfall in free flight 12 to 15 M. The color of the gas is light brown because of the unburned acid residue, which gives off H_2O and NO_2. During the tests, gas masks, for the most part were not worn. In the cross section outlet, the combustion chamber nozzle was set for a pressure of 0.85 atmospheres. At the termination of burning, the apparatus should have reached a height of 14 KM and speed of 800 M/second. Culmination point at 30-35 KM height. Striking range. (See sketch).



For the injection system, a twist nozzle will not be used, because of expense involved in lost apparatus. The firing of the apparatus ensures from a starting wagon which is driven over a concrete pit at the start. On the nozzle end of the apparatus sits a strong ring for the reception of the machinery container for the steering rudder. With these machinery containers (4 pieces) the apparatus sits up on the start wagon, where it is made fast with screws which are loosened shortly before the test start.

<u>Operation.</u>

Mr. Schuler responsible.

The trial values were transferred by means of measuring instruments with a potentiometer, over an electrical conduit to the writing apparatus.

At the combustion chamber burning trials, the following were measured:

Combustion chamber pressure, thrust, fuel consumption, and tank pressure. Oscillations were taken down on an oscillograph.

Flying targets were not as yet shelled.

Project with 4 tons thrust: (only on paper)

The same ballistic performance, and the same useful load as Waterfall.

Pressure demanding of the fuel.

(1) With a high pressure N2 present in Waterfall.

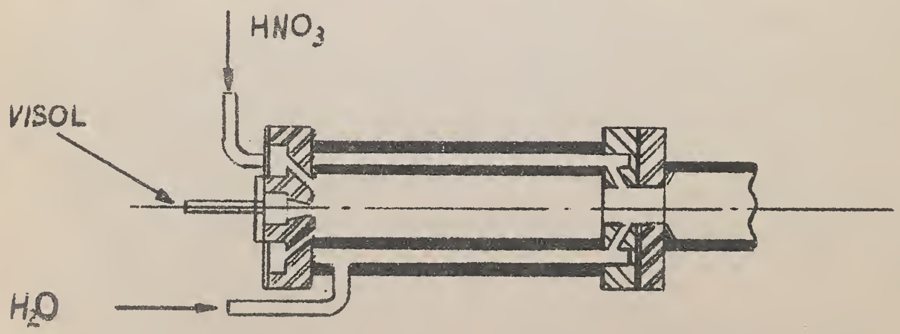
(2) With powder cartridge (components unknown) furnished by a Hamberg firm. The cartridges were tried out; they burned up too fast, however, (16 instead of 45 seconds) and gave off too high a temperature. Burned off at under 25 atmospheres.

(3) With a combustion steam installation. Visol with H2SO4 and HNO3 were completely burned under a water injection. The combustion took place in a burning chamber (see sketch). The finished steam was about 500°C.

Weight Comparison:

N2 sphere empty ... 180 Kg
N2 sphere full ... 250 Kg
Combustion steam installation filled ... 80 Kg
(Projected)

It is not especially known if a reaction takes place between the steam and fuel. However, this could not become serious. Until now, about 35 Waterfall apparatus were misfired.



Dipl. Chem. Gerhard Heller.

1. Heller was born on January 24, 1914 in Eschwege, he attended the Reform Realgymnas at Eschwege where he took his diploma on March 2, 1933.

His Post Graduate Courses were = Chemistry at the University Gottingen and at the Technical High School, Darmstadt. He specialized in Physical Chemistry, and passed his examination for title of Dipl.Chem. in the Spring of 1940. Heller's industrial work from May 1, 1940 until today was at the Elektromechanischen Werke, Karlshagen G.M.B.H. His duties there were in the Fuel chemistry and Thermodynamics fields.

2. Responsible offices and firms with whose cooperation work was done:

1. OKH, Waffenamt, Berlin, Kranzer Str. (Ordnance Dept.)
2. OKL, Technische Luftrustung, Berlin, Wilhelm Str. (Technical Air Equipment Board).
3. Experimental station of the Luftwaffe, Karlshagen West.
4. I.G. Farbenindustrie, Berlin, Koch Str. 74 Dr. Wagner.
5. Chemische Werke Schollern near Rathenau Director: Dr. Eberbach.
6. Schmidding, Bodenbach, Dr. Kaspar.
7. Reichsmonopolverwaltung, Stettin (Govnmt. monopoly control).
8. Technical High School, Dresden, Prof. Beck.

Hans Huter Parten Kirchen 16 May 1945

Hans Herbert Huter, born 21 March 1906 at Bern, Switzerland.

After I completed the Technical High School in Mainz, I went to work as apprentice mechanic for 3 and ½ years at the Chemical Apparatus Plant of A. Zierold, Aschersleben. In connection with this, I visited the higher technical institutes in Mittweida. After 5 terms, I passed the engineer examination with "good".

Due to the depression and lack of work it was impossible for me to get a post as engineer. In September 1927, I took a position as an assembly mechanic for iron and bridge construction with the firm of "Gutehoffnungshutte", Oberhausen, - Sterkrade. After 6 months of work, I received the position of constructor in the project department. I worked on statical and constructive problems in regards to steel construction, mines and iron-mine-works. For financial reasons, I left this firm in August 1929, and took the position of Ass't Manager in the Coke-Experiments Branch with the "Coke-Oven-Construction Firm" Dr. Otto and Co. in Bochum. In this branch, preliminary investigations were made for the construction of coke plants at home and abroad; in addition to this, large scale experiments were carried out on newly constructed ovens and plants for the recovery of by-products. After six months of this work as experimental engineer, I was promoted to the position of director of the "night shift" and was responsible for the continuous day and night experiments and for the operation of the normal coke plant including by-product recovery. In August 1930, due to economical reasons, the experiments were terminated, and the personnel laid off. For some time, I was unable to find any work. In March 1931, I was able to get a position as ass't mechanic for automatic-long distance telephone installation. At the "AFB" in Berlin. In a short while, I was mechanic at the long distance phone stations Bremen and Rostock. I was again laid off in March 1932. In April 1932, I joined the Free-Workers Organization "Rocket-Flight Field, Berlin", which was under the leadership of Diploma Engineer Nebel. Here, I worked mainly on constructive problems as well as problems of the liquid rocket and the testing and starting apparatus which were developed by the work party. Besides this, I evaluated experiments. After the flight tests requested by the City of Magdeburg with two larger rockets for 600 kg thrust were concluded with little success in the Spring of 1935, further apparatus could only be constructed with very small means, as the necessary support could not be obtained and industrial backing was only very small. In the Summer of 1934, the experimental work had to be discontinued. After 4 weeks of work with the Henschell-Aircraft Works in Berlin, I received a position as constructor with the Schwarz Propeller Works in Berlin-Waldmannslust. Since, if it was at all possible, I wanted to stay with the rocket experiments, after a year at Schwarz, I took the position of experimental engineer with the firm, Siemens, under Director Altvater. I worked in the department for Automatic Flight Control. Director Altvater already had given us his support at the Rocket Field (Raketenflugplatz), As far as possible. He thought that sooner or later science would take a greater interest in the rocket problem, and for this reason, put Riedel, Heinisch, and myself (all former members of the Raketenflugplatz-Berlin) into his Automatic Flight Control Department. Diploma Engineer Nebel also went to the Siemens Works after the termination of the rocket experiments but was in another department. The present professor, Von Braun, had already left the Rocket Flight Field since 1932 and joined the Army Ordnance. At the Siemens Works, I worked as experimental Engineer on gyroscopic course indicators and gyroscopic compasses for airplanes and automatic steering gear, under Prof. Dr. Fischel, (Former leader of the experimental station Ernst Udet). After 2 years of work, from August 1935 until July 1937, came Prof. von Braun and took Klaus, Riedel, and myself to the Heimat Artillery Park, Peenemunde, the place where liquid rockets were being developed and the first stages of the constructional work had been completed. With Riedel as leader of the experimental group, we soon put the test benches in order and

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carried the experiments (started at the shooting grounds Kummersdorf) with "Rocket-ovens" and the entire apparatus further to perfection. With the introduction of the V-2, as the first apparatus to be used for military purposes, the duties of the experimental department were increased to cover the development and testing of the necessary vehicle, casing, and firing equipment. With the increase of operations, my duties and responsibilities became larger. In the beginning of 1939, I was managing the operational part of the entire test field. Early 1943, I was Chief Engineer. In the Fall of 1943, they gave me the position of Leading Engineer of the entire testing fields. After the Heimat Artillery Park was turned over to the Electro-Mechanical-Works, G.M.B.H., Karlshagen, where the various departments constructed ground installations for V-2, were consolidated into one central direct "ground installation". At the death of the director, Klaus Riedel, the management appointed me to his successor. I held this position until the unhappy end of the war, which terminated our work for the time being.

Signed: Hans Huter.

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MEMORANDUM: Interrogation of Prof. Dr. ERNST HUTER, Kitzingen, 21 April, 1945.

Dr. Huter was interviewed by F/Lt Stokes and Dr. R. W. Porter.

Also a member of the Peenemunde group at Darmstadt, Dr. Huter claims to be an expert both in the field of electrical measuring devices, and also in the field of High Tension. The principal problems put to him by Peenemunde were (1) an electric pressure measuring instrument for all sorts of purposes (2) an alternative method for Brennschluss control for the A-4 rocket, and (3) a magnetic amplifier.

He mentioned two uses for the pressure measuring instruments, the first was for laboratory and testing purposes such as measurement of the oxygen pressure in the A-4 etc. The second required a very small type of instrument for measuring very low pressure differences in wind tunnel work. He says he has built pressure instruments from 1/1000 atmosphere to 70 atmospheres, for liquid and gases.

The integrator for Brennschluss control was not described in detail but in brief it consisted of a movable armature so arranged as to vary the frequency of two oscillatory circuits in opposite directions when acceleration is applied. This change in frequency causes a motor to run at a speed proportional to acceleration so that velocity is measured by the number of revolutions made by the motor. This checked the story given us by Buchhold. Dr. Huter stated that his device had not been entirely successful and had not gone into production. (A later concept based on Dr. Huter's written statement consists of two synchronous motors, one driven at the frequency of each tuned circuit. The difference in speed would then give an accurate measure of the acceleration and the velocity could be obtained by means of a differential gear and a counter.

The magnetic amplifier problem was put to Dr. Huter by Dipl. Ing. Scheer, a former pupil to Peenemunde. He thinks it was probably for the A-4 but not sure just how.

D. I. Kurschner and D. I. Knodgen at Steinbach bei Lohr am Main are two engineers who have a few machine tools and have been making samples of the pressure measuring devices and the accelerometers.

Dr. Huter claimed that all his work on high voltage problems came from A.E.G. and had no connection with rocket propulsion or with Peenemunde.

The problems had to do with substitution of other materials for mica in insulating materials, since mica was in very short supply. He experimented with specially treated paper and with tri-acetate sheets. Some of his work was intended to find ways to cut down the space required for high voltages by improved insulating and baffling techniques. He worked with voltages up to 1,000,000 volts rms ac and 2.2 million volts surge. He later correctedthis and said that the transformers he used for the surge voltages would not actually give that much, but were intended to. This work was done for Abt. Industrie, A.E.G. Berlin, N.W.40 for a man whose name he couldn't remember, but who was a former pupil.

One other development which Prof. Huter remembered working on was an instrument for measuring the torque in rapidly rotating shafts. The application he had principly in mind was that of aircraft engines.

R. W. PORTER.

HOFFMAN

interrogated Garmisch 22.5.45 by J. IBALL, H. A. LEIBHAFSKY, G. J. GOLLIN.

A-4.

He sat in a building and calculated the results of electrical measurements during static tests. He remembers the following statistics:

Thrust 25 tons.

Combustion chamber - pressure 14.7 atu.

" " temperature not measured believed to be 2000°C

Pump pressure - same on both pumps 25 atu.

Pressure drop in covering jacket 5 atmosphere.

rise in the covering jacket from 10°C to 40°C

Amount temperature in rocket near combustion chamber 10°C

Pressure in alcohol tank on stand 0

" " O_2 " " " 1.2 atu.

Turbine press, 3800 rpm at full thrust.

2000 rpm after vorkommands.

Fuel consuption 75 kilo O_2/per sec.
60 kilo alcohol/per sec
135 kilos/sec.

Starting load for lightingup 8-10 kg/sec of each fuel.

At first the flow for lighting up is by gravity and tank pressurized head but gradually the turbine speeds up.

Thrust measured by balance on A4 all measurements correct to + 1% - 2%

Chart travels 4 mm per sec
per travels 1 cm = 14 atu
width of track = $\frac{1}{10}$ mm

Wasserfall.

Thrust measurement by MESSBEIGL accuracy not very good + 1 to 2% or 2 to 3% error.

Schiler could tell but was not as good as the balance.

Various types of thrust spring were tried.

Doesn't know if full or ½ elipse.

Cannot give the test results as they varied so much as the plant was experimental.

Oscillographs only used for measurements taken in flight.

HUBNER, UDO

Interrogated H. A. LEIBHAFSKY 22. 5. 45
G. J. GOLLIN. Garmisch.

Worked on Prufstand 5.

Worked on turbo-pumps.

Came from Walter of Kiel.

(1) Turbine tested at 4000 rpm

In flight 3,600 - 3,800 rpm

Developed 540 h.p. yo 4000 rpm.

3-5 seconds to get to full speed.

The alcohol - On valves are open before the turbine starts.

Gas line to turbine lapped to keep steam warm and to prevent fire from alcohol leaks.

Small schluss at end of shaft (cam operated) cuts off T Stoff in case of overspeed.

(2) T - Z System. (T Stoff 130 litres
Z Stoff 10 litres)

Z Stoff must arrive first (otherwise explosion) it then operated diaphram valve and opened both main and solenoid T valves.

Mass flow 2.5 kg/sec $\frac{\text{T Stoff}}{\text{Z Stoff}} = \frac{14}{1}$

Steam temperature 400 - 420°C

Z Stoff kept hot by blowing hot air on outside of tank.

With atmos. temp. of - 20°C could stand two hours (dropped 30°C to + 5°C)

Reducing valve heated to avoid change in calibration as very sensative to temp. changes.

At Korkommando Main T Stoff valve shuts and turbine changes to 8 or 10 ton stage. Fuel flow cut to 1 third of normal.

INTERROGATION OF DR. GUNTRAM HAFT, at Partenkirchen
on 21 May 1945 by
F/Lt H.M.Stokes and
Dr. R.W. Porter

Dr. Haft, worked on the three computing elements for the Wasserfall, namely the "Einlinkrechuer", "Parallaxrechner" and "T-rechner". He came to Peenemünde in August 1944, and worked for Dr. Netger, under whon he was responsible for all"Bodengerät". Previously he worked on proximity fuses fo a small fi m known as Kramolin in Berlin. He had a solution, he says but others were better and his ork there was terminated.

The T-Recliner is ude for the purpose of resolving the control signal in such a XXXXXX way that they acto on the proper pairs of rudders. The rocket itself is stabilized X in roll, but depending on the problem it may have any position with respect to fixed coordinate system at the launching point. Since controls "up-down" and "right-left" are given with respect to this coordinate system, the T-recliner is needed to determine what signal shall be sent to each pair of rudders.

The computers were experimental types only and were in separate boxes having electrical inputs and outputs. All firings were made at the Flakstelle in the neighborhood of Bengin. No computing equipments of y kind were used for the test firings. The rockets carried radio remote control of the Kahl-Strasburg type, and generally the crew was happy if the rocket could simply be made to respond to the control. The computing equipment was being bench-tested in February; some of the components were in the laboratories of E.W. at Neue Bleicherode, the home of the Flakversuchstelle.

Very little work was actually done on the ground equipment by the X E.W.; their ork was chiefly to coordinate the manufacturers, such as Telefunken, Kreiselgeräate, etc, d to test the systems.

Dr. Haft seemed not to know out the detailed functioning of the computers. He referred us to Dr. Geisler and Dr. Elfers.

MEMORANDUM: Interrogation of HELMUT KEIL, 21 April 1945.

Source... This man was a courier acting chiefly as liaison between BHF Berlin (by whom he was employed) and Prof. Ludwig Wesch of Heidelberg. He had had some technical training but apparently had no degree. He had apparently prepared for the Allied occupation by setting aside copies of documents, samples of tubes, etc. encountered in his work. These he hid. In the period between 9 April and 14 April he turned over the documents in several lots to the AMG in Buchen which was near his home in Hettingen. The first set of documents which he turned were given, AMG says, to Maj. Wm. Saunders G-5, 21 Corps. Altho there was no charge against him, the importance of his documents and information was recognized so he was tken in custody about 14 April and brought to Heidelberg by Lt. Ryan, AMG. From Heidelberg he proceeded to Kitzingen where MFIU5 of the Seventh Army interrogated him. His documents were given by Ryan to Maj. Draper in Heidelberg.

Routine interrogation by the Seventh Army was carried out and will be covered by their reports. Advanse mimeographed copies of some sketches the subject made are attached. Technical interrogation of the subject was made by Dr. R. W. Porter and the writer.

Subject apparently feared and disliked Wesch, and every effort was made to keep Wesch unaware of the fact that the subject was under detention and was talking. Another reason for the subject's willingness to talk was the hope of special favors for his family. At his request AMG issued a pass for his mother permitting her to go out after curfew for a midwife for his pregnant wife.

Anti Radar Coatings --- Primarily for Schnorkel. Code name was Schonsteinferger. Material consisted of five layers per accompanying sketch. Proportions of materials in different layers differed slightly but averages were stated by subject to be (lampblack) 3-10%; Eisenpulver (powdered iron) 40-55%. The grain sizes of the powdered iron subject says are different in the different layers. The cones had flattened sides and sharp edges but an almost circular base.

Layers were attached in turn. The last layer with the cones attached was formed in a press using 200 atmospheres. Subject says there are forms at Messelhausen. There were many samples 40 to 40 cm at Messelhausen, probably buried. Several boxcars of material (two closed and one open car) left Heidelberg for Messelhausen on 26 March. They were seen to be near Heilbronn on 28 March. They are probably now along the route, either via Osterborken and Laude or via Nuremberg and Wurtzburg.

Absorbtion without the cones is said to be 30% and with the cones absorbtion is 70%. Material is said to be good for wavelengths from 2 to 180 cm. Curves of performance were among the documents surrendered to AMG. Subject stated that 10-20% of absorbtion was caused by rectification in the material which caused d-c in the surrounding water. He could not elaborate on this. Probably misinterpretation of something he heard. Besides Wesch, others working on this material are Dr. BOJEZ, Dr. VETTER, and Herren HAUSER and STETTER. Samples were made by Bunawerk of Schkopau located between Merseburg and Ammendorf.

Self-Steering Missile --- Subject's technical knowledge was weak and unreliable on this subject. He couldn't give a coherent story on the overall operation but some of his statements may fill in stories obtained elsewhere.

The missile was described as 25 cm long with a photosensitive device in the nose. Subject had not seen or dealt with the tail and motor and shell but says that they were to be built by Schaeffer and Budenning a Magdeberg firm which makes naval torpedoes. The code name for the whole missile is Fuhrernotprogram. The control apparatus was quite complicated involving four little motors to control the tail surfaces, and subject did not know how it worked. Leitz representatives were at the University frequently so subject thought they designed it.

The missile was said to be a self-starting and self-steering device. They were told that the seacoast of France would be blanketed with them to attack any planes from England that came over. The sensative device was said to be able to detect a soldering iron at 200 meters and up to 20 degrees off its axis. As subject had only seen single element sensitive heads he could not explain how the thing steered itself but drew from memory a circuit diagram (attached). An accurate original schematic was supposed to be among the documents he had surrendered.

Subject said that lead sulphide cells could be used for visible light detection but were not good for infra red. For the latter the "phosphor" type was used (subject's sketch is attached). The filter material supposed to exclude all visible light was called UG6. A modulated light is supposed to cause operation of the device. A perforated wheel is used during testing. Daylight does not cause operation, in fact a lamp is used inside the head when it is used at night in order to give the same operating point as during the day. Said lamp is sometimes an incandescent type, sometimes a mercury lamp.

Others besides Wesch working on this subject were Dr. KRUPPKE and Fraulein KAMM of Heidelberg and Messelhausen; Prof GUDDEN of Dresden; and Leuchstoff, GmbH, (a Telefunken associate) in Steinbach, Thuringia. Dr. KAMM was in charge of the work there.

Small Generators--- Telefunken or Bleupunkt built a d-c generator about 10 x 10 x 10 cm; 10-15 watt output. Output is 25 volts d.c which is said to be sufficient for some of the new electronic tubes.

The generator is driven from outside by a motor of similar size which operates on 6 volts d.c. A larger generator for 60 watts which is driven by a small gasoline engine is also reported.

CORFU Gerate --- Subject reported this to be for radar transmitting and receiving. After our inquiry about the magnetrons involved, the subject told us of hiding some tubes in his house that he was supposed to have delivered to Wesch. On the following day the subject was taken back to his home in Hetingen where he turned over the following:

5 Telefunken high-frequency tubes reportedly good for 60 watts output from 500 cm. to 10 cm. and to higher frequencies at reduced ratings. Type number LD-9.

11 Magnetrons of the RD-2 type. These are small magnetrons in which the anodes are about ¼ inch long. There are four anodes, alternate ones being connected in parallel to a two wire open ended tuned line enclosed in the glass envelope. The lowest frequency ones are marked RD2 Mod and are rated at about 10-12 cm. The intermediate ones, marked RD2, are rated about 8-10 cm. One sample of a much higher frequency one (probably near X band) is marked LM565. Several of the tubes have attached tags giving operating point data.

1 tube not previously encountered. It was marked RM4032. Subject reported it to be a magnetron whose frequency was variable from 2 cm to 18 cm just by moving the magnetic coils. It appears to be a diode with connections at each end for concentric line or cavities.

Suggested disposition --- The subject claims to have hidden some sample phosphor cells at Messelhausen. They may be old types but should be recovered by taking the subject to this location. Subject's technicel knowledge is limited and probably knows little more than he has revealed. Unless further interrogation is specifically desired, it is suggested that he be released to house parole.

W. HAUSZ. 23 April 1945.

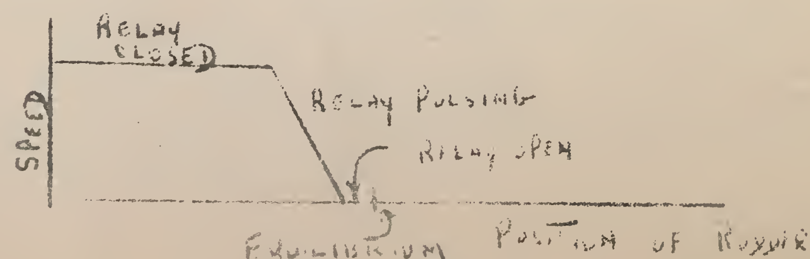
INTERROGATION OF DIPL. ING. JOHANN JOSEF KLEIN

By Sq/L Sharpe, F/Lt Stokes,
and Dr Porter, at
Partenkirchen

Ing. Klein was asked about the new servo-control equipment which he was reported to have worked on. He said that he had had samples in his laboratory but did not know details of the circuit. There are several different types, having time constants from 8-10 milliseconds up to 100 milliseconds. The 100-millisecond type requires an input of 1 to 2 ma into 400 ohms to produce a saturated output of more than 100 ma. The device is designed to control a K-12 servo-motor and is used in the automatic pilot for fighter aircraft such as the Me 109, etc. A 500 cycle AC supply with frequency regulation must be provided.

This magnetic amplifier was tested in model of the rudder control for wasserfall. Results were not very good because of the long time constant of the magnetic amplifier, as compared with an electronic amplifier. The time constant is particularly important in Wasserfall where the natural frequency (aerodynamic) is high, being of the order of 3 cps for lateral motion and much higher for roll.

Dr. Klein is personally in favor of the magnetic amplifiers, and thinks he could have overcome the time-constant trouble. However they were difficult to obtain, both because of a scarcity of mu-metal, and because each amplifier required twenty to forty manhours to produce. Since four amplifiers were required per rocket, the labor was considered too much, Electronic amplifiers would have been just as bad, and in addition there was a very severe"Bottleneck" in vacuum tubes. Therefore, the Wasserfall engineers were trying to develop a simple relay system which could be operated by the gyroscope pick-off and would control an electric motor. To keep the system from hunting the relays are caused to "chatter" or pulse at a frequency determined by the time constants of the relays themselves. This pulsing is produced by means of a feed-back circuit and gives a control which is similar to proportional control:



(Interrogation of Dipl Ing Johann Josef Klein, continued)

Dr Klein seems to be relatively enthusiastic about the relay system and believes it will be satisfactory for Wasserfall.

R.W. Porter

Interrogation of Dr. Oskar Lange (EW 2222) 5 June 1945 - By F/Lt. H.W. X Stokes and W. Hausz.

Born 1912. Worked at Heinrich Herz Institute, Berlin under Prof. K.W. Wagner from 1936-1940. He was concerned with magnetrons in the 10-20 cm range, in particular with the back-heating of the filament. In 1940 Dr Lange published a dissertation summarizing work done.

During this period he also carried out a research on the transmission of 1 to 5 meter short waves in the ionosphere. Used a 1 KW impulse transmitter near the Scharmützelsee in Berlin. This work was under the direction of Prof. Leithauser.

In 1939, October, Dr Lange was attached to the Erprobungstelle at Karlshagen, but was allowed to perform his work at Berlin. He was asked to prepare a summary of all available (German and foreign) papers on the transmission of short waves 4 to 1000 meters. This was completed early in 1940. Then he was sent to Rechlin to study beam control methods (Leitstrahlverfahren) under development by Dr. Plendl. At the time it was applied to the control of Ju 52 aircraft.

In April 1940, Dr Lange transferred to Peenemunde and in conjunction with Dr. Steinhoff, who is a good pilot, worked on the application of this beam control system to the He 111 and the Do 17 planes with three-axis steering control. A thorough grasp of the problems involved in effective control was desired. Experience gained was applied to the A 5 missile during 1941 and 1942. Similar experiments leading to the Leitstrahl control of A 4 were carried out in 1942 and 1943.

Subsequent to the development of the Leitstrahl, a 50-60 MC apparatus, Dr Lange worked on the development of the Leitlinie Verfahren. One of its aims was to reduce the possibility of jamming. It was tobe a 50 cm system. Much work was done but the development was not yet complete. It was being developed in conjunction with Dr. Jaekel of Telefundken.

To reduce the jamming possibility great emphasis was put on the design of the antenna for the missile. A Yagi antenna was developed, with three dipoles in line protuding either from the fin or the fuselage. This design gave a pattern with a forward to backward radiation ratio of 30:1 in voltage or 1000:1 in power. For 50 cm waves the influence of induced currents in the missile on the pattern was still large but not nearly so great as it had been at 50 mc.

As in the Leitstrahl, the system was basically a lobe switching transmitter with means to identify the two lobes. Plane of polarization distinction between the two lobes was tried but discarded and the final system modulated one lobe with one audio frequency and second lobe with a distinct audio frequency.

Dr Lange was charged with the development of control for Wasserfall, up to April 1944, but a flying accidiknt incapacitated him for six months and Dr Netzer took over this work.

He disclaims having deviloped control for A 9 as told us by another source but says that he had proposed a system but had not developed XXX it.

CIOS trip No. 183 Group II - Copy of report given to Group I.

INTERROGATION OF DR. LANGE AT GARMISE PARTENKERCHAN

JUNE 6th 1945

Interrogated by S/Ldr. B. A. Sharpe, RAE

SUBJECT OF INTERROGATION: "Leitlinie" decimeter steering system for V2.

Dr. Lange explained that the Leitlinie system was being developed as a replacement for the "Victoria Leitztrahl" steering system for V2.

Its main purpose was to reduce the possibility of jamming.

A wavelength of 50 cms was used and directional aerials were used both on th4 ground and on the missile.

The system used was the same as the Victoria Lietztrahl with the exception that the modulation frequencies indicating the mark space periods were higher, i.e. in the supersonic region.

GROUND EQUIPMENT

A Wurtzburg aerial system was used, fed from a cw transmitter. A commutator was arranged on the aerial drive to provide switching of the mudulation tones in the required sectors of the scan.

MISSILE EQUIPMENT

This equipment followed the same general circuit arrangement of the Victoria Lietzstrahl but the design would be made very much smaller and cheaper. This was due to the following reasons.

1) The directional aerials on the ground and on the missile produced a greater equivalent field strength at the missile allowing a quite simple design of superrengenerative receivers to be used.

2) The higher modulation frequencies used resulted in much smaller filters.
   The origonal Victoria equipment had dimensions 45 x 25 x 15 cms. While the new equipment was built into a cylinder 12 cms diameter and 18 cms long.

The aerials used on the missile were three element yagis mounted on the fins. These gave a back to front power ratio of 30:1

STATE OF DEVELOPMENT

This equipment was still under development at Telefunken. The engineer in charge was Dr. Jackel.

FUTHER ACTION

More information may be obtained through Dr. Brandt of Telefunken.

Larsson 16,June,1945
Knust
Nordt
Rupelt.

Introduction.
This interrogation continues and amplifies the report of 15 June, 1945 on the above men.
Meteor. This recoilless, high velocity gun was worked on in Sweden during 1940-43 by Larsson. In this device, shown in Fig.1, recoil is counteracted by a rocket jeet issuing from the breech of the gun. The pwoder charge made up of standard NC powder of thedimensions shown is distributed on either side of an ignition plate in the ratio of 3 parts forward and 2 parts aft. Ignition is produced by heating a wire which sets off a compressed black powder disk on either side of the wire. Current is obtained from the stray field inside the gun tube due to a coil wrapped around the outside of the tube. The interrogaters claim that they have made this dubious device work. After innition, rapid burning of the two charges raises the chamber pressure, accelerating the projectile and blwoing the bursting disk situated in the rear of the charge. From that time on the rocket jet from the rear is supposed to produce a force equilibrium with the normal gun recoil forces. The bursting disk is made from cast iron or preferably a steel reinforced plastic. The hemispherical cup sealing the forward end of the powder charge carries the projectile on a short extension of its forward surface. This cup is made from semicircular flat steel bands overlapping and moulded in plastic. On reaching the gun bore reduction the hemisphere is supposed to break up and pass out through the muzzle. The outside diam. of this hemosphere is provided with labyrinth grooves where it comes in contact with the large gun bore to prevent gas leakage. The interrogators claim that with a chamber pressure of 2000 atü the projectile velocity at the bottle neck will be 850m/sec and at the muzzle 1500m/sec. Higher pressures toward the muzzle end of the gun is given as the reason for the higher muzzle velocity. A light gun tube can be made to stand this pressure by a form of strip winding shown in Fig. 2. The winding is laid on in an overlapping helicel form in 4 to 6 layers under tension. Strips are made from a high strength, cold drawn Swedish steel of 160 kg/mm² elastic limit. The inner layer is made from stock .6 to 1 mm thick. Thickness is reduced in each layer until the outside layer is 0.2 mm thick. A thin outer tube is pushed over the assembly for protection. The claim is made that such tubes having a total thickness of 15 mm have sucessfully withstood 3000 atü. In order to obtain sucessful operation elasticity is necessary. Each layer of winding must slide axially on itself so that after several pressure applications a thin bright line shows near each rubbing edge. The projectile used in this gun is provided with the Tromsdorf device described in the 15 June interrogation of these same men.
This gun has never been built.

Klemmüng Ratio.
This ratio is defined as the area of burning powder surface devided by the throat area of the nozzle. For normal diglycol powder (for composition see report of 15/6/45 on these people) a ratio of 500 to 600 is normally used which gives a pressure of 150-200 atü.

With "Per Pulver" a ratio of 50 - 80 will give the optimm working pressure of 20 to 30 atu. A lower ratio is required since the burning rate of "Per Pulver" is about ten times that normal powder. When perforated powder grains are used the inner Klemmung ratio must be considered in order that the grain will not be burst due to internal pressure. For single perforation powder the ratio is defined as the area of the inner turning surface divided by twice the hole area. For security from powder grain explosions the inner Klemmung ratio must be less than the outer. With burning, the inner ratio decreases as the hole area (r 2) increases faster than the inner burning area (r). These people were asked again about the performance of Per Pulver. On test it has given a fuel consumption without an expanding nozzle of 4.5 gm/kg sec. With an expanding nozzle this would represent an SI of 277 sec.

This obtained by-

1. Higher temperature
2. Higher specific gas volumn
3. Higher heat content in the organic compounds (more H 2) giving better combustion products.

In addition this powder has a higher specific density than normal 1.2. 1.8 instead of 1.55. With further work it is hoped to obtain fuel consumption rates of 4.0 gm/kg sec without an expanding nozzle.

These men suggest that Dr. Teichmann be interrogated. He is in Wofratshausen about 20 miles north of here on the Munich road. Ruppelt, Nordt and Knust worked for Teichmann on fuel knocking problems and speak highly of his ability. This report repeats information gained from the interrogates with no special effort to sort out fact and fancy.

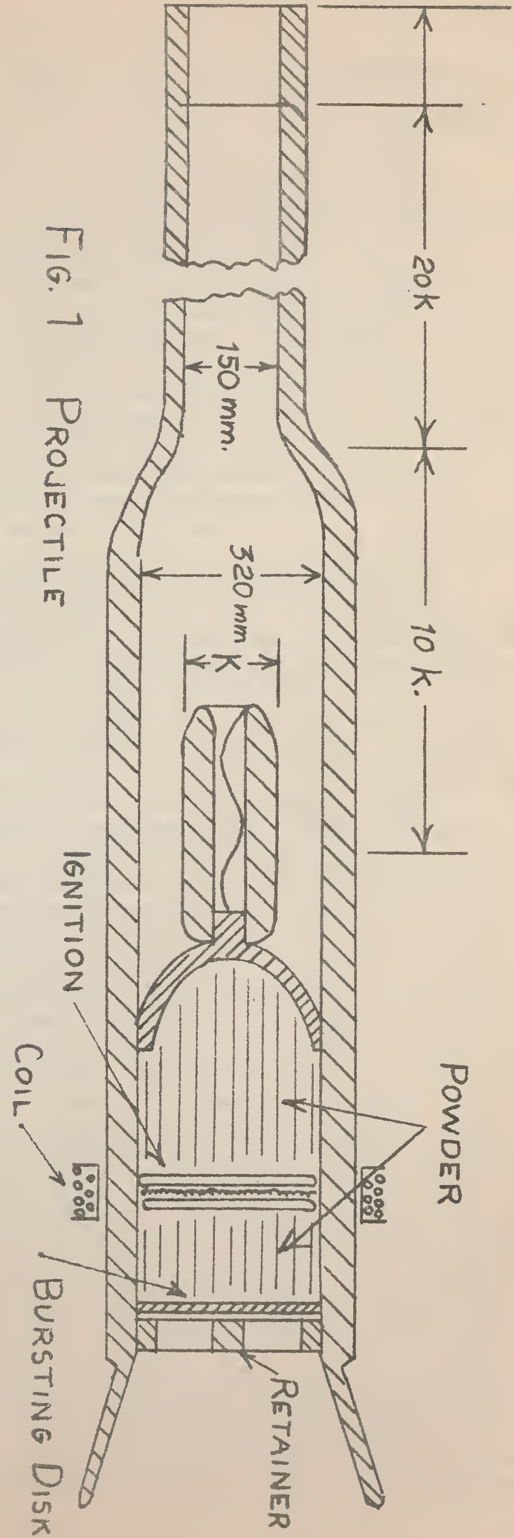


FIG. 1 PROJECTILE

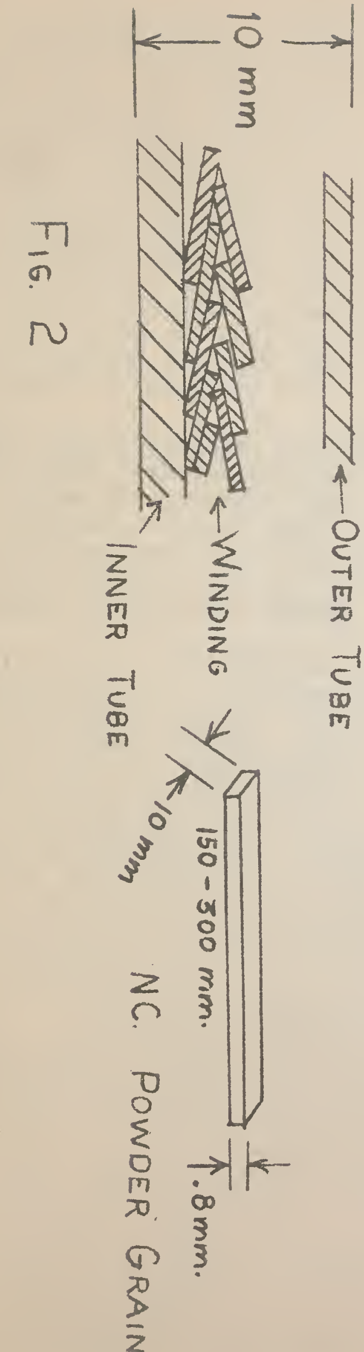


FIG. 2

Nils Larsson,
Engineer
Stockholm.

1. Larsson was born on 14 March, 1916 in Ostra Frolunda, Alvsborgs, Lan, Sweden. He attended public school in Rydobruk for 6 years, and the gymnasium in Halmstad, for 4 years. In addition to that he attended until 1937, the Chalmers technical high school at Gothenburg. Larsson began two years of voluntary service during latter half of 1937 at the Swedish artillery regiment in Stockholm, and later went to the reserve officers school which was situated in the artillery Schiesschule Skillingaryd, southern Sweden. Because of the war his training was prolonged and he was released in July 1940, since it was possible to familiarize himself with the different weapons used by the infantry and artillery units, he became interested in armament techniques. He was specially interested in the designing of portable guns and light portable weapons, since in his opinion the current types to be too heavy.

2. In the summer of 1940 he proposed a non-recoiling tank gun which was accepted by the Swedish armies weapons branch. For that reason he was transferred (as a civilian employee) to the Swedish armies weapons office in Stockholm. During that time he studied for two terms at the artillery engineering school of the Swedish General staff. In the fall of 1942, the tank gun was approved for manufacture, the Swedish infantry was issued with 3000 pieces (one persqued).

3. While demonstrating this weapon he came in contact with representatives of the foreign military attache; The Norwegian military attache (London Govnmt.), Lt. Col. Smith-Kielland (now ambassador to the royal Norwegian Govnmt. for the future Czechoslowakian republic) showed the American and British attaches some of his designs, for it was Larsson's wish, if possible, to go to America or England, and there continue his work in the interests of the united nations. There after he was invited to lunch by Major Balish the British second military attache, there healso met the American military attache; It was determined, in the interests of the Allied nations, to try and look into the possibility of Larsson coming either to England or America, and to work there in a certain development organisation. On this occasion he showed them several of his previous designs and outlined some of his further iseas.

4. By this time it was 1943 and the only way for him to get out of Sweden was by air, he was informed, however, by the British Military attache that he could'nt leave Sweden in that way under any circumstances. Besides which Larsson had became an official in the Swedish army weapons branch in Stockholm.

5. Instead the suggestion was made that he be sent to Germany in the interest of the united nations in order to work there till the end of the war and gather and pass on information concerning developments of weapons. For this purpose he was met by several representatives of the American and British secret services, from these men he received one months instruction on how to operate (for full particulars of his activities in Germany see Appendix No.---)

6. At the above mentioned demonstration of his weapon he also came in contact with the representatives of the German military attache, 1st.Lt. Muller-Liebenau who asked Larsson to pay him a visit in connection with sending him to Germany. Several days after, everything was set, on 22 May,1943 Larsson got his final instructions from a British secret service man, Mr. Abraham who was employed at the British legation in Stockholm. Larsson gave him his latest drawing for future development. On the same dayhe traveled by train to the Swedish-Norwegian border, there was taken in hand and escorted by a Swedish engineer who was working offices were located in Berlin-Schmargendorf, Berkaerstr 35/36 near Alster Platz. On 1 July, 1943 he was employed by Magét, Berlin Tegel, this firm belonged to "Verwertungsgesellschaft", Montan, a dummy corporation (Tarngesellschaft) with which the leading weapons firms were connected. Among them being Rheinmetall Borsig, the firm of Maget is also connected with Rheinmetall Borsig, it is the leading firm in the field of light machine guns (lMG Modell 42). For other particulars concerning the Maget to see his special report appendix No----)

7. In order to carry out his registration and in order for him as foreigner, to advoid any trouble he was given a helping hand from the former chief of the security police and the S.D., SS-Hauptsturmfuhrer Skorzeny. At the same time he was interrogated by the Gestapo and seized by the criminal police for the German secret service, they crossed the border about 5km. south of the Charlottenburg customs station.

8. In accordance with the talks of the German military attache in Stockholm, Larsson was transported to Oslo by German military police via an office of the German security police, and the S.D.(security service) in Norway. He was kept in Oslo for approx. three weeks because his entry papers had not been completed and the entry could be regulated from that point only. On 18 June he went abroad the troop transport S/S Monta Rosa and sailed for Aarhus, Denmark, and from there continued his journey by railroad via Hamburg to Berlin, where he arrived on 23 June, 1943.

9. Larsson had a letter of introduction from the German "Heereswaffenamt" for the firm Maget,Berlin-Tegel, and also an order to report to the Chief of the security police and the S.D. whose (other particulars concerning his meetings with higher German police authorities see Appendix No.----)

10. In order to really grasp the situation it should be explained that the above mentioned S.S. Hauptsturmfuhrer Skorzeny had in the meantime completed his action of liberating Mussolini. For that reason he became a very influensial and well known personality in Berlin, which of course was to the advantage of Larsson. Skorzeny could be very helpful when Larsson was introduced into the Reichs ministry for Armament and war production (chief weapons board), into the army weapons section, and to Chief of the S.S. weapons section, Brigadef, Gartner, in other words to all the leading authorities in the field of development of weapons. Those authorities he told of his suggestions, as per instruction obtained in Stockholm, he was then,after long and difficult negotiations with several German authorities (see personnel files), transferred to the Versuchs-Anstalt Grossendorf, Westprussia situated on the Hela Peninsula.

11. In the meantime ten months had gone by and he was still waiting for word concerning his suggestions on developments.

12. Here at the Versuchs-Anstalt Grossendorf, he had the best possible chance to break into R-technique since at this institution the work in this field was going on very throughly and systematically. It was carried on under the leadership of Ing. Rolf Engel, one of the oldest rocket specialist of Germany. This Versuchs Anstalt maintained the closest ties with the Raketenflugplatz Leba on the Baltic, where General Dornberger and Prof. Orthmann were developing the A-4 long range rocket, later called the V.2. They had made several complete R-Arbeiten (reports?) for this rocket field and through these Larsson was very well able to follow the developments of the V.2. He sent his reports in reference to this, to Stockholm through the two ways at his disposal. One; through his contact in Berlin; two through his own correspondence (Particulars herefore see Appendix No.----).

13. Here he also came in contact with the leading men of the Torpedo Versuchs Anstalt Gothenhafen a branch of the Kriegsmarine, Versuchs Anstalt Kiel and also with the chief of development of the Navy, Prof. Walter, including his developing station on the Hela Peninsula. Furthermore he had connections with the development section of the Technical High School Danzig and the special developing section of the firm Menke in Zoppot which had the task of carrying out special high frequency studies.

14. Since in the winter 1944-45 the imminent Russian drive into Prussia made the position somewhat dddicult it was decided to move the Versuchs-Anstalt Grossendorf, West Prussia to Pibram, Czechoslovakia and there, in conjunction with the Waffen-Union Skoda-Brunn GmbH., Werk Pribans (which had already been under the Direction of Ing. Rolf Engel for one half year to form the Versuchs-Anstalt of the Waffen-Union, Pibram. The intentions were to erect one powerful development station through the combining og the two mentioned stations. For that purpose one of the most modern testing benches for rocket-technique was planned, and errected here (approx. 8km. from Pibram) All the endangered development sections in Germany, that is controlled R-weapons, were transferred to Pibram. Besides that the most qualified techniques in the field of R-technique were brought together here.

14. Since Germany's imminent capitulation was at hand it was decided to break up the organization and let the workers move out of Czechoslovakia. This was Larsson's favourable opportunity to place his personal files, which were in possession of the firm, into safe keeping, besides that, while moving out, it was Larsson's good fortune to accumulate and save several very important apparatus and drawings in the development at R. which were dispersed throughout southern Germany. In addition to that it should be said that his wife (who is living with their two children in Stockholm) has in no uncertain manner forwarded his reports in Sweden, and has kept and is keeping in contact with the people who had sent him to Germany in the first place.

15. On the return of the last transport out of Czechoslovakia May 4th. they were overrun by American troops near, Laufen a.d. Salzach and per his Stockholm instructions, immediately reported to the first American officer he saw. He happened to be Major Brooks, chief of the spearhead of the 20th. Armoured Division who after one week put Larsson into the custody of Major Covington of C.C.A. of the same division.

Per the latters orders Larsson was sent to XVth. Army Corps (Capt. Davis) in Salzburg and from there to 7th.army Headquarters in Augsburg where he and part of his group have stayed since May 10th.

Augsburg 6 June 1945.

Millinger.   Garmisch 19 May 1945

Millinger proved to be a difficult man who was reluctant to talk. He was born 7 May 1920; was educated at an Engineering School, Frankenhausen, after which he worked as a mechanic. He went to Peenemunde on 29 December 1939, and worked on A-5 (4 - 5 meters long, rather less than 60 to 80 cm diameter, no pumps).

Questioned: (1) Regarding Potentiometer & Contact in main 02 valve. Former used with oscillograph in test shed. Latter by Thorpe in the field.

(2) Regarding cal. pum. diaphragm switch. Operated at 1.3 atu - permitted the electric E202 byepass valve to open. This diaphragm switch is the Rubidpentak!

Interviewed 19 May 1945.

INTERROGATION OF DR. NETZER, EW 224, re Wasserfall.
By F/Lt. Stokes 24 May 1945

1. Wasserfall is known in altogether four modifications designated W-1 to W-4. It was intended to use the letter "V" but this was not adopted as it became the collective notation for offensive weapons. (V-1 and V-2

W-1 Onlyx one or two missiles type W-1 were produced and were, for examplè, the only sub-types in which the fuel tanks were made of aluminum.

W-2 About five examples made of the second variation of Wasserfal. The aerodynamic feature of the shell of W-1 was retained, but the lateral dimensions (span) of the wings and the tail unit was reduced. (See atched Sketch 1). Another sheet metal fuel container replaced the aluminum ones of W-1. The servo mechanism was fully hydraulic and was supplied by LGW. Not all five w-2's were fired, a number was destroyed or damaged.

W-3 The aerodynamic shape of W-2 was retained and little change made in the "interior fittings", except in the layout which was altered. Also, the hydraulic servo gear, was replaced by an electric-hydraulic system known as K 12. Originally it was planned to produce 170 w-3's but is was curtailed to 70. In fact only some 40 W-3's were made. The majority of the components were made by private industry, the tail unit of the shell only was made at Peenemunde. However final assembly of Wasserfall took place on EW 326 under the direction of personnel from VKN.

W-4 Resenbled W-2 aerodynamicaly, but incorporated a fully hydraulic servo-mechanism of LGW limited to an effective time of 70 secs.

2. According to Dr. Netzer parts of Wasserfall were transferred to Neu-Bleicherode in the course of the general move. The new location was XXXXX known as EW 224 and was housed in surface-workings immediately outside the village (Dr. Netzer could personally direct anyone there, should an opportunity be offered). He does not think that a complete Wasserfall is to be found, only parts, mainly noses, centre sections and tail units.

3. Wasserfall reaches a supersonic speeds after 18/19 seconds from start, remains at supersonic level until 70/80 seconds from start and after about 90 seconds from start ceases to respond to control.

This time of 90 seconds is called "Gesammitioirkungsgrad" and is the me during which the missile maintains a higher velocity than the veloc- of the target. It is also called "Treffzeit" or the time during which it is possible to obtain a hit on the target. The time of the "Gesammtevirkungsgrad" is also the time where the missile is maintained under contro

XXXXXXXX

This time is limited also by the life of the DC batteries carried ad in the case of sub-types using fully hydraulic servo systems, by the amount of oil available. Again, a limiting factor may be the efficient expulsion of the fuel from the reservoirs.

According to Dr. Netzer, all calculations on the expected performance of Wasserfall were made on basis of a total control tome of 70 and 90 seconds, with a maximum burning time of 40 to 42 seconds. It had not been decided yet whether 70 or 90 seconds was the limit. In the case of the latest sub-type, W-4 a "gesarmmtwirkungszeit" of 70 seconds was provided with fuel requirements chosen accordingly. In this case also the oil requirements of the fully hydraulic servo mechanism by LGW were limited, to an endurance of 70 seconds. (the oil pressure to be used was 60 atü, and was to be obtained from the Nitrogen bottle reserved for the fuel expulsion).

The speed of Wasserfall is said to be over 330 M/Sec after 70 seconds and 140 m approx. after 90 secs.

In XXX view of an expected shortage of lead, considerable work was carried out with a view to replacing lead batteries by primary batteries. This was done by Inlg Wunder, the work was however far from complete. The lead batteries normally useed could be heated. This was not in fact done, the batteries being well insulated and maintaining a suffieient temperature during ordinary usage.

5. Provision was made for the incorporation in the nose of some form of homing device. However, nothing at all had been decided as to the precise kind of device ultimatelXy to be used. Work was proceeding in this direction at various places. At Peenemunde itself Dr. Weiss was working on an infra-red device. Dr. Weiss was concerned only with the device itself not with the link to the Servo-mechanism.

Work onX the latter problem was carried out by Dipl. Ing. Geissler and Dr. Ludwig. It was hoped however ultimately to make the missile and its hand control fully automatic, but up to the present this problem and the general control problem was very far from being solved.

Actual firing trials at Peenemunde were effected without the presence of a homing device and without the use of any formX of target. At one time, some form of searchlight control was comtemplated, but after mathematical examination of the problem this proposal was dropped. Work on steering control problems of Wasserfall was carried out at Peenemunde by Dipl. Ing. Ernst Geissler and by Dr. Ludwig.

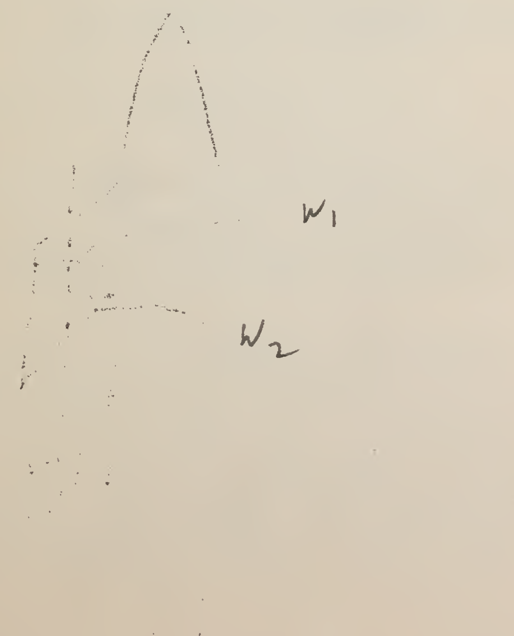
(Interrogation of Dr. Netzer, continued)

5. Maximum height reached by Wasserfall is approx. 25 kms. The max-ímum Range range is said to be about 40 kms.

6. All modifications of Wasserfall were fitted with Jet rudders (Strahlruder). Both graphite and hardwood (probably oak) types were used. Wood is sufficient as the rudders are required only during the initial subsonic period (up to about 12 secs from the start). Methods had been developed for Jettisoning graphite rudders, wooden types are allowed to burn off. Work on Jet rudders was carried out by Ing. Ratt.

7. The distance of the launching point of the missile from the control gear is about 20/30 meters. According to Dr. Netzer it is <u>not necessary</u> to align the missile in any way at the start, but it is said to be done in a crude way frequently, to assist the operator at the controls. *stop here.*

Sketch 1 By Dr. Netzer re Wasserfall



Garmisch-Partenkirchen, May 22, 1945

Interview with Hans Nikutowski

Interrogator: Dr.F. Zwicky CIOS 183.

Worked on the mixing ratio of the propellants on V-2. A diaphragm with hole was built in of correct size (obtained from hydraulic handbook) to get the correct flow of oxidizer and fuel. Came originally to Peenemünde October 1940 and worked on the construction of the combustion chamber (= Ofen, or Heizbehälter). Was a detail draftsman on a job.

Interrogation of Dr. Theodor Netzer, 18 May 1945.

By: Dr. R. W. Porter and F/Lt. Stokes, Partenkirchen.

Introduction.

Dr. Netzer did not come to Karlshagen until March, 1944. What he did prior to that time is know known. He said he had written it out in his "Lebenslauf", however, no copy is on file in our office.

At Karlshagen, he was immediately assigned to Wasserfall. Since he arrived rather late, he occupied himself primarily with organization and planning rather than with detailed engineering. At that time, he says, the technical direction came from Dr. Von Braun and the military direction from Obs. Lt. Dr. Halder.

According to Dr. Netzer, Wasserfall was the only really high-speed AA rocket planned. It was handled by a special group at Karlshagen and partly for this reason Dr. Netzer felt that it suffered somewhat from lack of interest. When the move was made away from Karlshagen, the Wasserfall group was established in a carriage shop in Nene Bleicherode, about 13 km from Bleicherode proper.

General Operation, Wasserfall.

It was planned that Wasserfall should have a maximum velocity of 800 M/sec but the highest velocity actually obtained was about 600 M/sec. The maximum angle of attack without stalling or instability was supposed to be about 8° in the supersonic velocity region and 15 degrees in the subsonic region.

The rocket is fired from a stationary platform of tubular construction, arranged with wheels so as to be easily transportable to and from the site. No attempt is made to turn the launching platform so that a reference line points toward the target; the control of the rocket is symmetrical so this is unnecessary. The trajectory is straight up for the first six seconds after launching. The rocket then comes under the control of a computing system known as the "Einlinkrechner" the purpose of which is to bring the rocket into the line of sight as quickly as possible without causing altitudes in excess of the maximum. The altitude is calculated at all times by another computing device known as the "T-Rechner". During the final part of the trajectory, the control is "line-of-sight" target information being obtained either by radar (Wurzberg, or Mannheim), or by special A.A. theodolites. The rocket is controlled by an operator, both during the transition stage, and during the final stage, who watches an illuminated spot on a C.R.O. tube and moves a "joy-stick" control in such a way as to bring the spot to the intersection of two lines. The two computers mentioned above plus a "Parallax Rechner" transmit their information automatically into the system so the operator's job is quite simple.

The velocity of the rocket reaches a value equal to the speed of sound about seventeen seconds after launching. Shortly before this point, considerable difficulty is observed with control instability. Wasserfall is said to have an excellent aerodynamic design from the viewpoint of constancy of center of pressure on the rudders, but according to Dr. Netzer it is still not indeed.

The dimensions, weights, propulsion data, etc. given in the Osenberg files agreed with Dr. Netzer's information with the exception that Salbei is used instead of liquid oxygen, the burning time is 42 seconds rather than 45, and that infrared homing has not actually been tried, but only proposed.

Details of Control Equipment.

The rudder servo is a standard hydro-electric unit known as K12, also used on the Ju 88, built by Luftfahrt Gerat Werke (L.G.W.) Berlin. An electric servo using a 600-800 watt motor with a three-stage reduction gear has been designed by Dr. Ing. Nickles. The A-4 rudder servo motor was not used because it was too slow and too weak. The K12 was chosen because it was available in large numbers. The A-4 "Mischgerat" is used because no other standard device was available. It was hoped that a specially designed control system might be used on a second model of the Wasserfall. Such a system, considerably simpler than the first has been worked out by Dipl. Ing. Klein, using a magnetic amplifier.

The specialists on the overall stability problem are Dipl. Ing. Geissler and Dr. Elfers.

The radio control principally used was the familiar Kehl-Strassburg system, also used on the HS 293. A few samples were obtained of a new set known as the "Brigg-Kozge", made by Telefunken at Berlin, and later at Summerfeld near Breslau. This set uses a transmitter having the code name "Kran" and a receiver simply "Brigg", or "Brigg-Kozge". This radio system, Dr. Netzer believes, was to be used quite generally as soon as it could be put in production. It operated on the same principle as the Strasburg-Kachl, but used a wavelength of about 50 cm. and was harder to jam because the frequency could be varied. According to Dr. Netzer, "Kran" permits transmission in 3 channels simultaneously. (Information later obtained from Dr. Wurster of Messerschmidt indicates that "Kran" transmits four simultaneous audio tones for controlling four functions, and can be easily adjusted to any one of twelve different carrier frequencies). Dipl. Ing. Walther, a high official, who remained in Hohenpeisenberg, should know all about this.

The radar sets used for obtaining line of sight information were either Wurzberg or Mannheim, usually the latter. Centimeter types of radar were beginning, but had never been used. The accuracy obtainable with the Mannheim is about 1/10 degree probable error when not jammed by "window" or other counter measures.

The transition computer, "Einlinkrechner", had two forms. One was a mechanical type known as "Gummiband", worked out by Dr. Ludwig who remained at Bleicherode. One of his assistants, Dr. Eichler, is here. The other computing device is an electrical system worked out by Dr. Elfers. All of the mechanical computers were made by Kreiselgerate, Berlin, later at Nieder Spiegll and Buchner, who may have gone to Bleicherode.

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Testing.

A four-channel telemetering system called "Messina I" was used for telemetering gyro-data, rudder position, pressures, temperatures, and so on.

About forty rockets were fired altogether. Many exploded because of failures in the propulsion unit, particularly at first, but there were seldom any failures which were attributable to the control equipment.

Homework.

Dr. Netzer has agreed to write a short history of the Wasserfall project and to have it ready by Monday, 21 May.

Interrogation of Dr. Theodor Netzer.

1. Dr. Netzer did not come to Karlshagen until March 1944. What he did prior to that time is not known. He said he had written it out in his "Lebenslauf", however, no copy is on file in our office. At Karlshagen, he was immediately assigned to Wasserfall. Since he arrived rather late, he occupied himself primarily with organization and planning rather than with detailed engineering. At that time, he says, the technical direction came from Dr. von Braun and the military direction from Obs. Lt. Dr. Halder. According to Dr. Netzer, Wasserfall was the only really high speed AA rocket planned. It was handled by a special group at Karlshagen and partly for this reason, Dr. Netzer felt that it suffered somewhat from lack of interest. When the move was made away from Karlshagen, the Wasserfall group was established in a carriage shop in Neue Bleicherode, about 13 km from Bleicherode proper.

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a. The rudder servo is a standard hydro-electric unit known as K12, also used on the Ju 88, built by Luftfahrt Gerat Werke (L.G.W.) Berlin. An electric servo using a 600-800 watt motor with a three-stage reduction gear has been designed by Dr. Ing. Nickles. The A-4 rudder servo motor was not used because it was too slow and too weak. The K12 was chosen because it was available in large numbers. The A-4 "Mischgerat" is used because no other standard device was available. It was hoped that a specially designed control system might be used on a second model of the Wasserfall. Such a system, considerably simpler than the first has been worked out by Dipl. Ing. Klein, using a magnetic amplifier.

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4. <u>Testing</u>.

a. A four-channel telemetering system called "Messina I" was used for telemetering gyro-data, rudder position, pressures, temperatures, and so on. About forty rockets were fired altogether. Many exploded because of failures in the propulsion unit, particularly at first, but there were seldom any failures which were attributable to the control equipment.

Interviewed 18 May 1945.

RADIO CONTROL O ASSERFALL

INTERROGATION OF DR. Netzer & Dipl Ing Walter.

By S/L Sharpe and F/Lt Stokes.

The flight of Wasserfall can be divided into three parts:

(1) From launch to the point of entry into the Radar Beam.

(2) Line of sight control up the beam which is kept directed at the target.

(3) The final stage during which control is transfered from the ground to a homing device in the missiles.

It wasstated by Dr. Netzer that space had been leftin the nose of the rocket for the homing equipmentbut as yet XXXXXXXX none had been fitted. However, the use of homing was very disarable as it reduced the possibility of jamming by a transmitter carried on the target aircraft.

Velocity during flight

The duration of flight during which control could be exercised on the rocket was between 70 and 90 seconds, depending on the type. Of this time the fuel only lasts for from 40 to 45 seconds. After launch the velocity rises until after 18 seconds the velocity reaches the supersonic region. After the fuel is exhausted the speed drops until at maximum usable range the speed drops XXXXXXXX to 280 mph. Above this speed radio control cannot be used for aerodynamic reasons and also the speed is not sufficiently in excess of that of the target aircraft to permit effective attack.

Aiming and firing

Two Würtzberg Radar sets are used one of which is used to track the target aircraft and the other to track the rocket. On the approach of an aircraft likely to present a suitable target it is picked up by the appropriate Radar sets and itscourse plotted.

The term "Treffbereich" is used to describe the surface enclosing t the volume in which the aircraft must be at the instant of firing of the rocket if a hit is to be possible.

Tables were being complied in Berlin from which the instant of firing could be obtained from measurements of aircraft course,height, speed, etc. Allowance is made by the commander of the site for the particular conditions existing during any attack.

METHOD OF CONTROL

Fully automatic control had been considered and would be desirable but so far were based on control by an operator.

The angular bearings from the two Radar sets are transmitted by a remote indicating system in general use for other purposes. These two bearing indications are to be displayed on a single cathode ray tube. The target aircraft is represented by a spot at the centre of t he tube face. The bearing of the rocket relative to the target is indicated by a spot, the position of which indicates the course error in two axes.

The reading on this tube is an indication of bearing error. No correction is made to the scale of the display to make allowance for change in range. The scale of the display is therefore constantly changing.

The conditions of control are also varying due tochanges in the width of the Radar beam and also to the speed of the rocket and to atmospheric conditions etc. The control is also complicated by the fact that it is arragged that the rudders in the gas stream should be either jettisoned or be made of wood andso burn off after about the first 12 seconds of flight.Dipl Ing Walter had been given the problem of designing the apparatus to provide a variable gearing between the control joy stick and the rate of turn produced on the rocket to make allowance for the above changing conditions. It was proposed to do this by a timed cam arrangement operating a potentiometer controlling the modulation of the ground transmitter. However the design had not progressed very far and the conditions for which he had to design had as yet not been definitly stated.

The operator used a joy stick type of control. During the flight he assumed that the display showed the relative positions of target and rocket to a fixed scale. No rate term was introduced automatically into the control system and the damping was introduced by anticipation on the part of the operator.

The signalling system used was a modified version of the Kaehlgeräte used in the F X 1400 and H S 293. Two apirs of audio frequency tones are used, one pair for azimuth and the other pair for elevation control. Each pair of tones is keyed at a rate between 20 and 25 cycles per second in the manner of "Mark-Space" keying.A 50% mark space ratio corresponds tostraight, 100% of one tone represents maximum rate of turn in one direction and 100% of the other tone represents maximum rate of turn in the other direction. Intermediate ratio provide variable rates of turn.

The keying is operated by a motor driven device and that keying ratio is determined by the left of a cam which can be varied by the position of the joy-stick controller.

The modulating oscillators and the transmitter are the same as those used for the Kaehlgeräte. The radio frequency used is approximately 50 MC/S. A simple dipole aerial is used.

The reciever is identical to that used in the Kaehlgeräte. In this receiver the four modulation frequencies are separated by filters, rectified and arranged to operate poparised relays. These two relays will therefore key at 20 cycles per second with mark-space ratio depending on the signals arriving on the azimuth and elevation control channels. A fixed DC volts keyed by these relays is fed into a unit known as the Zustazgeräte. This unit contains rectifiers and filter circuits and provide smoothed DC signals of amplitude corresponding to signals on the control channels.

AERIALS ON WASSERFALL

Metal strips mounted on the trailing insulated edges of the rudders are used. These are of similar design to those used on the A4.

NEW RADIO CONTROL SYSTEM TO BE USED IN WASSERFALL

New equipment both for the rocket and on the ground was being developed by Telfunken. This operated on a wavelength of 20 to 23 cms. This equipment(known as either Kram-Brigg or Kahn-Brigg) is more fully described in a report on the interrogation of Dr. Leo Brandt and Dr. Paul Kotowski of Telfunken.

This equipment used the same control system as the Kaehlgeräte.

However due to the much higher Radio frequency used advantage can be taken of the use of very directional aerials thus reducing the possibility of jamming.

The aerial on the ground equipment consists of a dipole with parabolic reflector which is mounted on the side of the mirror of the Radar set which is tracking the rocket. This arrangement allows a very narrow beam to be used. This increases the field strength at the receiver thus permitting the use of a reciever of low sensitivity. A directional aerial will also be used on the rocket but the design of this is not yet known.

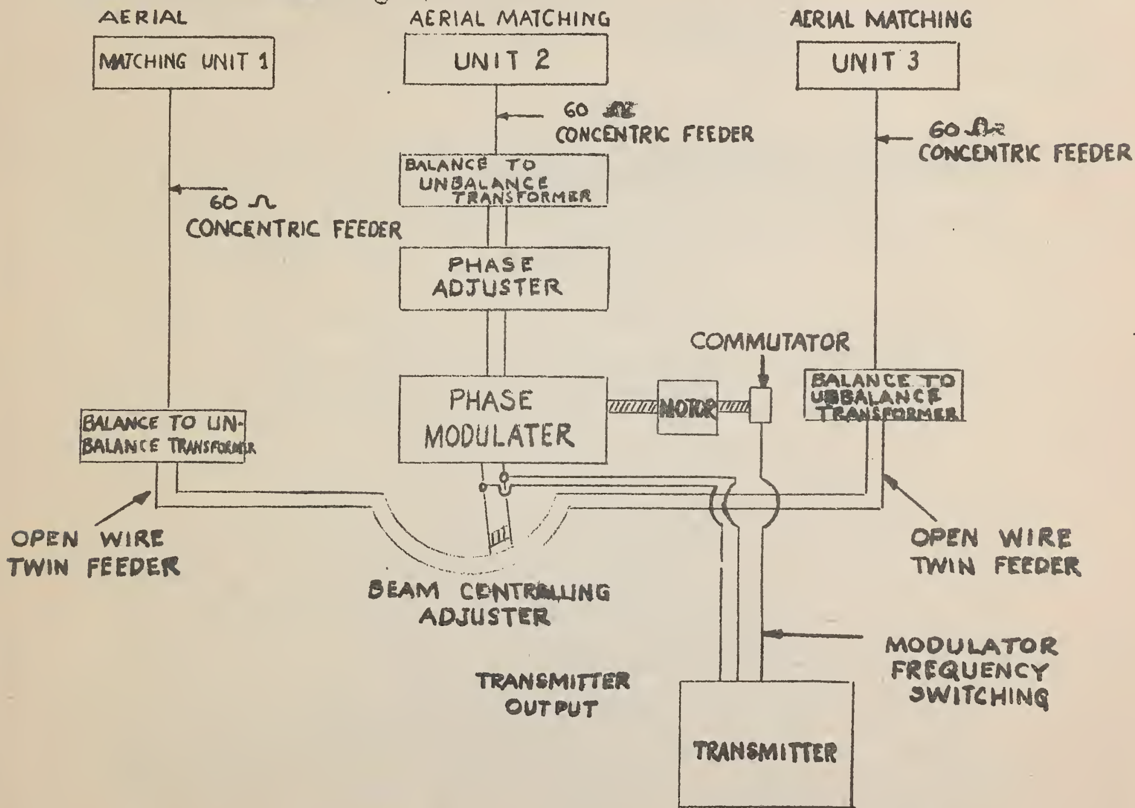
CIOS trip 183 Group 11 - Copy of report given to Group 1.

Interrogation of Dipl.Ing. von Ottenthal at Innsbruck, 6th June 1945.

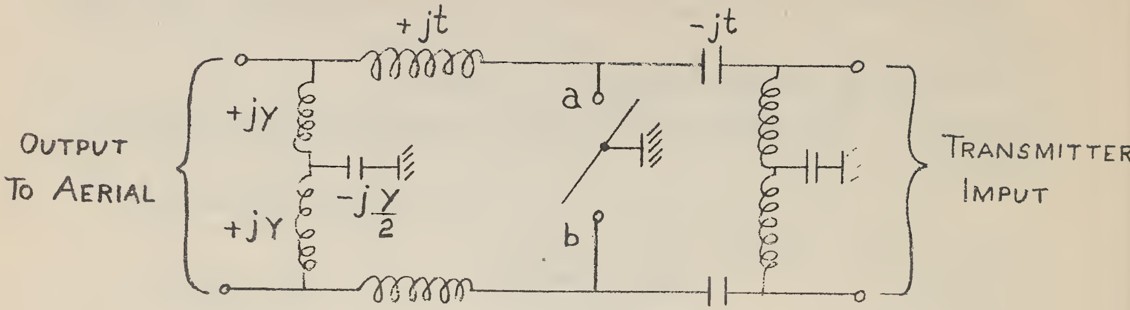
Interrogated by S/Ldr. Sharpe. R.A.E.

Subject of Interrogation "Victoria Leitzstrahl" control system for V.2.

Dipl. Ing. von Ottenthal gave the following description of the ground equipment of "Victoria Leitzstrahl" equipment used for the steering control of V.2.



A block diagram of the ground system is shown above. The system worked on a frequency of 42mc/s. The three aerial systems were the same and each consisted of a dipole 0.44 long with a reflector of the same length spaced quarter wavelength from it. The aerials were mounted at one wavelength above the ground. The distance between the outer aerials was 20 . The transmitter used was the Lorenz 500 watt Blind approach transmitter type A.S.I.



Circuit of Phase modulator Unit

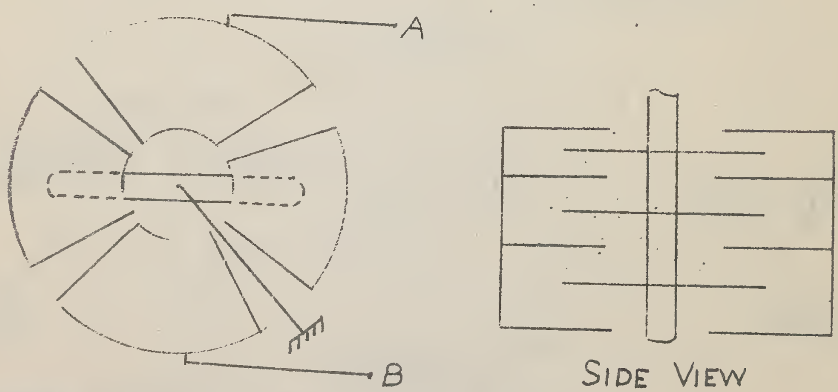
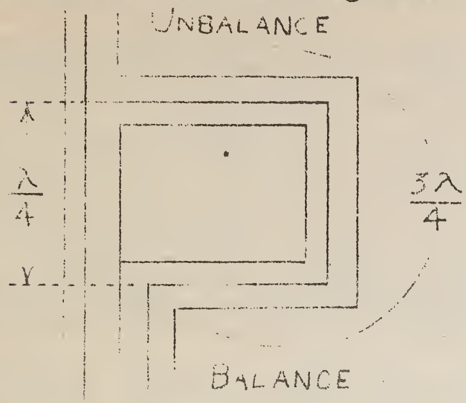


Diagram of motor driven capacity switch

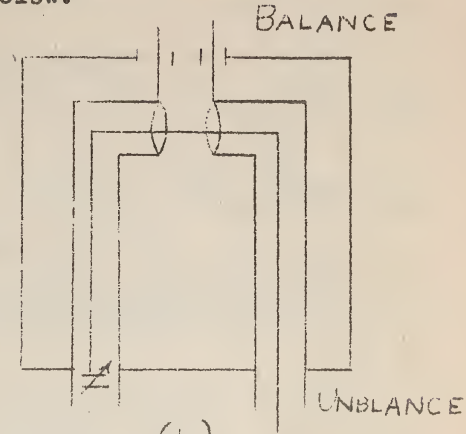
The motor drives the capacity switch at 3000 r.p.m. and gives equal open and closed periods. On the motor spindle a commutator is mounted arranged to switch the transmitter modulation frequency. This frequency was open and 5000 c/s during the period for which it was closed.

The phase modulation produced a beam swing of 1°. The beam width is defined by Lorenz as the angle between the two points at which the $\frac{V5000}{V7000} = -1.05$. For the Victoria Leitzstrahl system this angle was 1 second of arc.

Balance and unbalance transformer - Two types had been designed: these are shown diagrammatically below.



(-a-)



(-b-)

The system shown in diagram (a) was the one that was used although it had the disadvantage of being frequency sensitive. The system shown in diagram (b) was not so sensitive to frequency variation. This was a later design (Lorenz) but only an experimental model was constructed.

Installation of system

Lorenz engineers had installed the system at Peenemünde in 1941 and had carried out tests with an aircraft. Dr Stienhoff of Peenemünde was the pilot.

Monitoring

In order to maintain the directional accuracy required of the system continuous monitoring was necessary. A receiver similar to the aircraft equipment was installed on an island off the coast (about 6 Kms) on the centre line of the beam. Steady reading meter indications from this equipment were sent back to the transmitter site first over a decimeter radio link and later over a submarine cable. These indications were displayed on a centre zero meter and an operator kept this meter on zero by adjusting the beam centralising knob, controlling the phase balance to the outside dipoles.
In order to obtain correct phasing of the aerial systems correct feeder lengths had to be used. Also as the phase modulator circuit had to be resonant the system could only be worked at one Radio Frequency.

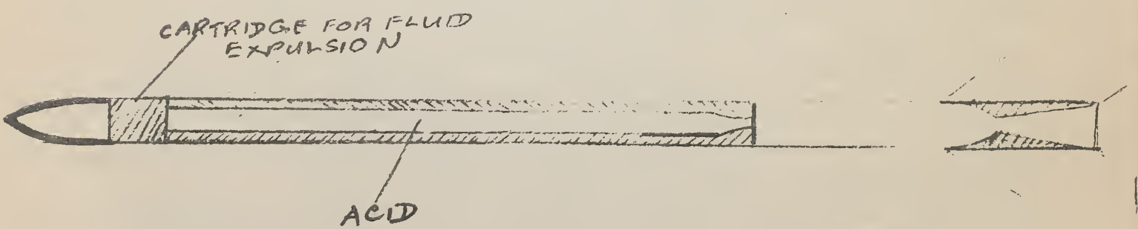
Karl Reilman

Age 26. Engineering school Bad Frankelhausen (not diploma). Left school Nov. 1939. Went to Army; later Peenemunde 4.1.1940 Test Engineer on A-4 and C-2 (Wasserfall) on the same test stand w s Taifun.

TAIFUN

10 cms dia. 2meters long. Fuels Visol and Nitric. On test bed N_2 expulsion but in flight done by powder. Whole operation 2 or 3 seconds. Flight tests. No cooling of the combustion chamber. Tested statically. Thrust readings were taken by means.of a hydraulic piston.

Reilman then drew a diagram of the TAIFUN showing powder cartridge and the bursting diaphragms which are situated at either end of the acid container which itself is contained in the fuel tanks



Garmisch-Partenkirchen
May 19 1945.

Interview with Kurt Patt.

Wasrecently since September 1943 occupied with the supervision of the construction of the "Wasserfall" body, war head, propulsive power installation and control gadgets. After theoretical stress analysis, model tests were made. All tests made were static in nature.

Greatest difficulties were encountered with acid proofing the "Wasserfall" device. (Patt does not know exactly what the "Saureabtragung" = yearly wear of the materials in contact with mixed acid was).

Pressurization problems at great accelerations of the device also caused some trouble.

1938-43 Patt worked on the A4 in a similar capacity as above.

A number of failures of the V2 were caused in particular by insufficient strength of the mountings of the propellant tanks which were very thin (1 mm - 1.5 mm).

Zellenbruche (failures of the outer shell) were also quite frequent at the beginning.

Mounting of the graphite rudders cause relatively little trouble.

Tightening of the feed system was not too difficult.

("Dehnungssicken" =

flexure joints had to be watched to guard against ruptures).

(Schematic drawing of the test installations for A4 will be supplied by Mr. Zoike).

1930-1936 Mr. Patt worked at Orenstein und Koppel, Waggonfrabrik, Berlin. (Mainly work on hydraulic and pneumatic brakes)

Ing. Kurt Patt 16/5/45

<u>Career</u>

I was born on the 18/3/13 in Berlin. At the age of 14 I graduated from the 73rd Publue School in Berlin, and began serving as an apprentice in Technical Drawing, from 1/5/27 to 31/3/30, at the Waggon Building firm of Orenstein and Kappel, Berlin. During my apprenticeship I attended the trade school for Metal work and took evening courses in Mathematics, Electricity, Physics, and descriptive Geometry. After the conclusion of my apprenticeship, 1/4/30, I began working as a technical employee and worked as a Draftsman, detail designer, and designer of trucks, large container trucks, and automatic unloading trucks until 11/5/36.

From 1/10/30 untill 1/4/30 I attended and graduated from evening classes of machine construction in Berlin. On 15/5/36 I changed my job and went to the Ernst Heinkel Aircraft Works as a designer. In Sept 1936 I got married. In Nov 1937 and in May 1940 our children Peter and Jurgen were born. Immediately on taking over my new job, my firm placed me at the disposal of the Army-weapons section- at the firing range, Kummersdorf, which was under the direction of Dr. Von Brunn, and worked in the "R-Gebiet". I also worked in the designing bureau under Herr Riedel, as a designer and independent design assisting in the development of R-Tanks and valve design for assisted take-off devices, as well as the airframe design for the A-3 apparatus. In addition to this were designs for testing benches and projects on calculating trajectories (Line of flight) for long range apparatus, which were to serve as the basic fundamentals for the A-4.

On May 15, 1937 I was requested by the Experimental station, Peenemunde and began my duties there after a large part of the personnel from Kummersdorf had also been moved to Peenmunde.

As group and main group chief I was put in charge of airframe design of the A-5 as well as the planning of the complete details of master designs for the A-4. This included also the estimation of fual compacity. Beginning Feb 1942, I worked on the airframe construction and the comprehensive designing for all the A-4 apparatus. As co-workers I had at my disposal, Group Leader Dipl Ing Marzek, Dipl Ing Palm and Ing Kroll with their respective staffs.

In Sept 1943, as the A-4 was in its finishing stages, I was contracted to work as section leader for the development and design of the apparatus "Wasserfall" (Waterfall). This project was for mass production at the beginning of 1945.

As co-workers I had at my disposal the following, Herrn Mrazek, Bedurftig, Palm, Osf.Kroger, Burose, Giese, Austen, Holderer and Ko[illegible]. While working at the apparatus "W", it was found that if it was constructed somewhat smaller, a definite reduction in consumption was achieved, while maintaining the same performance. The workers on this apparatus went as far as the final design stage but were interrupted on account of our moving

Career - Index

Born: 18 March 1913, Berlin

Finished School: 31 March 1927

Apprentice: 1 May 1927-31 Mar 1930

Trade School and Courses: 1 May 1937-March 31, 1930

Designer at firm where apprenticeship was taken; 1 April 1930-May '35

Machine construction school: 1 Oct 1930 - 6 March 1936

Designer at Ernst Heinkel: 15 May 1936 - 14 May 1937

Began work at Peenemunde: 15 May 1937

Group Leader: May 1938

Main Group Leader: May 1940

Section Leader: Beginning August 1942.

INTERROGATION OF DR. ROSENTHAL!

BY Dr. ... Sharpe on 28 May 1945.

The purpose of the interrogation was to obtain information on Infra Red equipment and general Infra Red development in Germany.

Dr. Rosenthal detailed his career and his connections with Infra Red work. He carried out two years of research between 1934 and 1936 in the John Hopkins University at Baltimore U!S.A. He there carried out general optical research involving Infra Red.

In 1936 Dr. Rosenthal returned to Germany and started at Dresden under Prof. Tomaschak. He carried out investigations into the catalitic action of phosphons, the aim being to obtain a relation between the condition of the phospors and the spectrum in the Infra Red region.

In 1939 he became an assistant to Prof. Beck at the Institute of Automobile Engineering in Dresden. He was here engaged in the measurement of flame temperatures in internal combustion engines in connection with work by Prof. Beck on anti-knock fuels.

Dr. Rosenthal was called up for the army in Sept. 1939 but was released again in Dec. 1939, when he returned to the Institute of Automobile Engineering in Dresden. He then carried out work still under Prof. Beck, on the detailed design of the burners and combustion chamber of the A 4. He carried out tests with water cooled probes to trace the course of the chemical reactions in different parts of the flame.

Prof. Beck was called to a job in Berlin in Sept. 1940 and the work at Dresden came to an end.

Dr. Rosenthal then joined the optical firm of Seitz at Wetzlen. Together with work on general optical instruments, hewas here involved in the design of Infra Red Telescopes,for German Air Force and Army use. The parts of this equipment peculiar to Infra Red,eg. the phloorescent screen, were designed and produced by A.E.G. under Dr. Schaffernicht.

Leitz developed and produced the lenses and the mechanical parts such as the tube, mountings, focusing arrangements etc. Leitz assembled and delivered the complete telescopes. These were made in a large variety of sizes. These telescopes were the only Infra Red equipment with which Leitz were concerned!

Dr. Rosenthal was called again to the Army in 1942 and went to Russia. He acted as an ordinary Infantry man until May 1943, when without warning he was called to Peenemünde.He first worked on the design of the combustion system of the A 4. In this work he acted as a theoretical physicist. However due to his preference for optical work he was transfered to a Dr. Weiss section to do work on homing systems.

A homing system had been developed but as this was the responsibility of Dr Weiss he would prefer that Dr Weiss should talk about it. They were proposing to use normal types of photo cells for Infra Red detection. They had purchased cells from Zeiss of Dresden. They had not used Bolometers as they were considered to be too delicate for use in a rocket were it was exposed to severe vibration.

A thermopile had been considered but it was not possible to design one that had a fast enough response. The photoelectric cell used was of the lead sulphide type.

Dr. Rosenthal was also involved in the design of the optical arrangements for the aiming of A4 on the launching platform.

It appears that Dr. Rosenthal had had several years experience in the use of Infra Red. Although he knew that a lot of work on Infra Red was in progress in Germany he had no contact with it outside the Peenemünde Group.

Biography of Dr. Eng. Martin Schilling

1. Domestic Particulars:

Born October 1st 1911 in Hoerde, Westfalen, the son of a city building engineer, Fritz Schilling. After living in Westfalen until 1930, then moved to Hannover. In 1930, married Annaliese Lange. Two children were born, Gerd and Hartmut, who are living, at present, in Knesebeck, District Gifhorn.

2. Education.

Attended the 9 grade secondary school at Dortmund Hoerde. Graduated 1930. Went to a Technical High School in Hannover to study physics. Received diploma there in October 1934 with high honors. After one year of military service, continued studies as candidate for doctor's degree and assistant to Prof. Hase, the professor of the Technical High School at Hannover, specializing in heat measuring techniques and technical physics. Doctor's degree December 1937. Grade of examination: Very Good. Specialized in the following: Mensuration of heat, especially optical pyrometrics, optics, industrial mensuration and practical mathematics.

3. Occupational Practice.

During his time as assistant from 1935 to 1937, carried out important work for industrial works of chemical production and lighting technique. On January 1, 1938, he became work manager and member of the business management of the Pyro Werke, Gmbh, Hannover, special factory for pyrometer constructions.

Gmbh, Hannover, special factory for pyrometer constructions. (Special Fields of work in the temperature regulation technique, optical pyrometry, and especially temperature measurements.) Worked in conjunction with the Kaiser Wilhelm Institute for Iron Research, German Iron Mines personnel at Dusseldorf, Professor Rummel and Dr. Guthmann, as well as Dr. Maser of the German Conduits Works. At the outbreak of war, put in the replacement forces. On December 1, 1939, was deferred for projects at Peenemunde. Became superintendent for the power units. In 1941, took over all power tests of the latest developments of rockets. On September 1, 1943, after the completion of the work department, became director of the testing dept. and in addition was the inspector of all the parts of A-4 made by subsidiary. Testing equipment for series production of the A-4 was being planned by specialists from their own personnel.

The association with similar places in Germany, in particular testing grounds, was comparatively small as their importance both quantitatively and qualitatively was inferior to the installations of Karlshagen.

A plan forced the developments of the different type flak rockets to be put at use at Karlshagener experimental station. The time then came to move the Elektromechanische. On Feb. 5, 1945, they ceased to work. In the few weeks before the occupation, it was impossible to set up an experiment plant at the new area at Bleicherode and Lehesten.

Signed: Martin Schilling.

MARTIN SCHILLING [illegible]

Interviewed by R.A.L. G.T.G., 1.1, B.A.3. Garmisch 20 May 1945. Age [illegible]. Doctor of Engineering 1937, Tech. High School, Hanover. Worked for Piroworks, temp. measurement to August 1939. Went to Army 30 November 1939 to H.A.P.11 on 1 December 1939. Discharged from army.

Began as leader of measurements group then later Head of Experimental Section in charge of all experiments.

Worked on A 4 - A 5 (had A/2 expulsion

Taifun (50 kilo all up?

Taifun used N2 gas for expulsion on the test stands but various cartridges were tried. No definite decision as to which was best. Thrust 700 to 800 up to 1000 kilo. No accidents with nitric. Believed he would use the same fuels as for Wasserfall. Not much difference between Visol & Optolene. Never used H2O2 in these devices.

A 4 4.8 gms/kilo sec = 85 of theory 2100 m/sec

(Best on A 4 equals 4.6 gm/kilo sec

Visol & acid equals 5.3 gms/kilo sec.

The various fuels used with HNO3 only made a difference of plus or minus 0.1 gms/kilo sec. The cooling alcohol (surface only makes a difference of 2 to 3 in the thrust.

__Wasserfall__

__Timing of fuel arrivals.__

Difference of opinion in small rockets doesn't matter. In large rockets found good procedure for the acid to come first.

__Metal brushes for timing Accuracy?__

Sometimes as much as 1 sec. difference in timing. Acid is the shortest path including the coil combustion chamber 1700 to 1900° C. (On A 4 always the O_2 to come first in order to establish steady flow.

__Taifun__ 67924

Venturi of mild steel. Could use the same venturi for 5 runs, then renew. Temp. of venturi at end of 2 secs. up to 300 or 400° C. Thrust measured with well fitting hydraulic piston about 2 cms in dia.

Interview with Dr. Helmut Schmid.

1. Since 1941, Dr. Schmid was occupied with the optical survey of the orbits of the V2 and with geodetic surveys for purposes of new plant installations. He also determined the instantaneous location of airplanes for the purpose of checking data which were obtained with electrical methods.

2. Optical Surveys. Two complexes of observation stations were established to survey the beginning of the path and the end of the path. Cinematographic transits (theodolites) were used to record azimuth and elevation photographically up to ten frames per second. The object was followed in a guiding telescope by two men operating the two coordinates, The surveying instruments, "Askania" in Berlin. In good weather and with a focal length of one meter, aperture 12 cm, the V2 could be followed up to a distance of 30 km. In general 4 to 5 observation stations followed the V2 simultaneously. The position at 30 km distance can only be guaged to within 3-5 meters.

As a second method the (Phototheodolit)was used. Stereoscopic pictures were taken 8 km apart and evaluated with the stereo- comparator. Problem of correction due to steady and fluctuating refraction in the atmosphere lies in between the corresponding problem of ordinary geodetic surveys and the problems in astronomy where the refraction through the whole thickness of the atmosphere must be taken into account. Because of the large distances involved, the curvature of the earth must of cause also be taken into account.

[illegible]. Because of the difficulty of picking up the projectile at the end of the orbit, especially in daytime, the point of impact is determined by acoustical pickups. As long as the explosion accurred on the earth's surface there were no essential difficulties to this method. However, it was more difficult to determine the height at which a projectile prematurely exploded.

4. Schmid worked on the data obtained from the Doppler method survey of the velocity time function of the V2, and on the "Hochzieltriangulation" (high target survey) in order to establish accurate bases at the island of Bornholm (which belonged to Denmark, at a distance of 120 m from Peenemunde). For this survey "Leuchthomben" (flares) were set by airplanes at a height of 6000 m. The flares were parachute suspended

Interview 19 May 1945.

Doctor Ing Ernst Steinhoff.

1. Personal Data.

Born on the 11 Feb 1908 in Treysa/Kr. Zeigenhain as the son of the Technical Inspector for the Reichsbahn, Ludwig Steinhoff. From 1909 to 1929 I resided in Kassel, finally in Darmstadt, Konigsberg/Prussia and Bad Frankenhausen.

In 1936 married Hilde adee (nee). Of this inion four children were born, Hans Joachim, Hannelore, Monika, and Gizela.

Original residence Darmstadt, later Peenemunde. They were evacuated to Weringerode/Sudharz in the vicinity of Bleicherode.

2. Educational Training.

Attended the 9-grade High School at Kassel, final examination was in the new year 1929, finally studied at the Technical College Darmstadt. Studied airplane construction avaition meterology, applied mechanics, selected capital of the higher mathematics, general electricity, wireless techniques, high frequency techniques. He received his diploma in the final examination of May 1933 with a rating of very good.

After the conclusion of studies, during the practising of his profession, engaged in further work on the questions of technical physics, flight instrument techniques and soforth. Received a promotion in 1940 from the Technical College, Darmstadt with the prediction of good.

During the studies in the years 1931 to 1933 engaged at the same time, with the Rhon-Rossitten experimental society on subjects of the aerological measurements, flight performance and aeronautical radio transmitions.

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In addition to a purely technical education took flying instruction. In 1923 glider training; in 1931, power flight training, and completed in 1938-1939 training in all classes of land planes, with a blind flying permit, also held the 1935 gliding world record for distance from Wasserkuppe to Brunn (504) km. Also participated in numerios air races.

4. Professional Practice.

1925- 1926 one year with the Dietrich airplane works. Afterwards, Raab-Katzenstein airplane works, Kassel. In 1929, 2 months with the Air Weather station in Kassel. In the following semester vacation considerable practice with the department of energy economy, overhead cables, over head cables monitoring etc.

After the conclusion of studies from May to October 1933, worked with the German-Russian Air Traffic company in Koenigsburg, as mechanical engineer.

For health reasons he changed to the engineers school, Bad-Farnkenhausen, as a lecturer and section leader for the Air Transport division.

He was occupied for 3 years teaching subjects on airplane construction, propeller construction, aeroplane statics, general statics, simplified construction, and airplane research laboratory work.

In October 1936 he returned to the Ernst Udet experimental body, thus working under Prof. Georgii on the subjects of aerologie, flight mechanics, Radar techniques, following through with flight performance measurements of numerous engines, and gliders, range measurements of airborne radio equipment, flight testing of tow gliders, and the subject of automatic pilots also.

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On the 1st of July 1939 Transfered to the army's testing station in Peenemunde and took over the supervision of steering gear, and later the testing department. At the end of 1939 he divided the subjects of work with Doctor Theil, from Kummersdorf, who took over engine development. Working with the same sectors of the electrical and radio equipment, and of free flight experiments, also flight mechanics and finally remote control, including equipment testing with a complete experimental testing airplane.

On May 1st 1942 he received the rating of flight captain from the Reich Minister of Air Transport, on the grounds of the experimental re results obtained in the airplane engine experimentation.

On the 1st Sept 1943 put in charge of the electrical equipment of the Heimar-artillery park 11, and later the electric mechanical works at Karlshagen.

In the following time, occupied in supervising the manufacture of electrical parts of various additional sub-firms for A-4 equipment, especially taking care of the developmental experiments of the A-4 in free flight, by providing processes for transmitting mensuration values from flying and the further development of A-4 apparatus for instance A-9. Since 1939 he was engaged with a fluid pool up to 30 leading German Educational Institutes for special problems of the production of the A-4 and for the furthering of the basic improvement of general rocket apparatus.

Working together with the leading radio firms in the production, experimentation, and fittings of radio installations for A-4 apparatus and Waterfall. (Wasserfall)

At the end of 1944 was commissioned to take over the development of all unmanned controlled German flying craft together with Reichs-

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Minister Speer. As a result of the removal from Karlshagen and the development of the war this commossion could not be put into practice.

Signed; Dr. Ernst Steinhoff.

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A5 ENGINEER AUGUST SCHULZE 16 May 1945

I was born on the 23rd of November 1905 in Neulaubusch. A son of a farmer, Mathies Schulze. From 6 years to 14 years I went to the Grammar School of Grube Erika.

After I quit school I worked for two years till April 1922 by Ilse, Bergbau A.G. in Grube Erika as Technical Draftsman. At the same firm for 3 years I learned Machine Fitting.

I attended the following Institutions:

Municipal Trade School in Berlin-Charlottenburg.
Specialist School in the City of Berlin (Night school).
From 1.4.1926 to 27.3.1930 City Machine Construction Night School, Berlin, and the State Recognized Machine Construction School.
From 1.4.1932 till 12.8.1935 I did these professions by the following firms:

Gebr. Reichstein, Brennabor Works, Brandenburg, 6.5.25 to 22.6.25 as Auto Mechanic.

Friedrich Henkel, Auto Repair Works, Berlin-Charlottemberg, 30.6.25 to 21.8.25, as Auto Mechanic.

Hartel Works, Limited Co, Berlin-Staaken, 25.8.25 to 12.9.25, as Machine Fitter.

Markus M. Bach, Berlin-Wilmersdorf, 13.9.25 to 14.12.25 as Electrician.

Brenta Electric Apparatus, Limited Liability Company, Berlin-Charlottenburg, 15.12.25 to 31.12.27 as Factory Technician.

Knorr-Brakes Limited Co, Berlin-Lichtenberg, 21.1.28 to 19.10.34 as Constructor.

Knorr-Brakes Limited Co, Berlin-Lichtenberg, 20.10.34 to 31.1.37, as Free Lance Engineer.

Kummersdorf Firing Range, Proving Station West, 1.2.37 to 28.2.37, as Constructor.

Army Test Station, Peenemunde, 1.3.37 till the present day, as Constructor, and Group Leader in the Contruction Bureau.

By the firm Knorr -Brakes in Berlin I was chiefly Constructor of Air Brakes for narrow gauge railways and air pumps with rotating pistons. To these belong valve and pipe line apparatus. Besides the preparation of designs and workshop drawings I have supervised the carrying out of tests in the workshop and conducted tests of newly developed apparatus on the testing field.

In the last 3 years I was with the same firm in the sales bureau as Free Lance Engineer with project work. I was occupied on price card-indexing and preparing Tenders.

Since 1.2.37 I worked under Dr. Dornberger and Prof. Dr. von Braun on the Rocket Problem.

I began on the Kummersdorf Firing Range as Constructor, and then prepared designs for a self-starter, which were completed later in Peenemünde.

Finally I worked with Ing. Tessmann on No.1 test bench at Peenemünde (Project and internal installations including provision of telescopes).

On account of the shortage of personnel this work had to be continually interrupted and I worked on the A-3 and A-5. On the A-5 apparatus I constructed the oxygen tank and the nitrogen condenser. Furthermore I undertook the comprehensive work of the whole apparatus including the development of a suitable high speed parachute for the ascent of the apparatus after its take-off.

The constructive control of the A-4 consisting of the following experts was in my hands:

Work-Department	Manager
Assembling	Deppe
Cells	Kroll
Water Heater	Neubauer
Turbo-pump	Bedeirftig/Menke
T-Installations	Paul
Tank	Finzel
Tool shop	Horn
Pipe system	Fuhrmann/Fischer
Electric connections	Kuberg/Mahler

The person immediately over me was Superior Dipl. Eng. Dannenberg, who also signed as responsible for the testing of apparatus. The additions to basic expenditure were worked out with Eng. Tessmann.

Albert Schuler:

Age 30. Technical High School, Darmstadt. Diploma Engineer 1939. Worked for 2 months on materials (not connected with weapons) at Rheinmetall Borsig. Never in Army. Went to H.A.P. 11.

Worked on A-4 and Wasserfall instrumentation.

Problems: (1) Special instruments to investigate troubles.

(2) Registering readings at a distance.

(3) Measuring (a) Pressures.

(b) Temperatures.

(c) Fuel Flow.

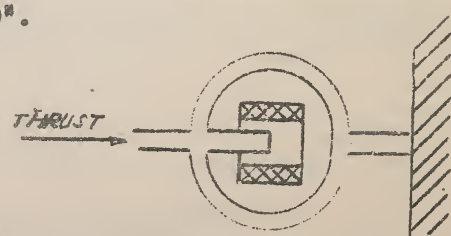
(d) Tank Contents.

The observation post was 200 to 300 meters from the A-4.

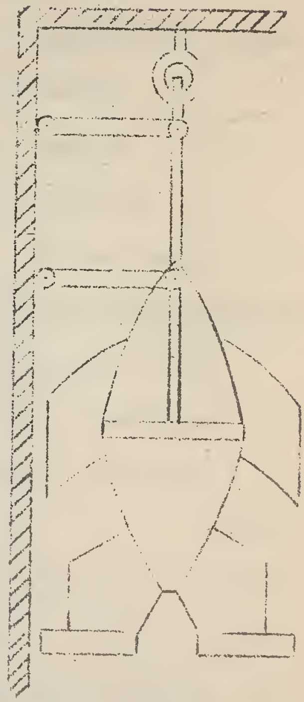
Thrust Measurement.

(1) As in A-4, used a lever weighing machine.

(2) By eliptical electro-magnetic ring gauge. Ring special steel W.A.V.Z.A. 7" x 10". Deflection 1½ mm for 8 tonnes thrust. 800 . Under best conditions accurate to 1%. Mechanical side O.K. but bad electrical trouble due to temperature fluctuations and changes in frequency. Measurement by A.C. Inductance Bridge. The Wasserfall gauge made to resist acid corrosion (He had not



used and possibly not heard of a win strain gauge. Method of measuring the thrust of the Wasserfall:



Temperature Measurement.

(1) Steam for turbine 380°C.

(2) C.C. temperature tried by Radiation Pyrometer, but this gave an indication only.

(3) The alcohol was not cooled appreciably by passing through the L.O_2 tank.

(4) Z. Stuff was heated outside electrically. If the gerät stood too long without being fired, it was sometimes necessary to heat the Z Stuff by blowing in hot air (externally over Z Tank)

Instruments used thermocouples - iron - constantin.

Cu - constantin.

Pressures.

(1) Used Bourden tubes on which were mounted rheostats which transferred the reading to Bunker 200 m. away.

(2) Condenser gauges.

(3) Siemens electric pressure gauge.

(4) In flight, Bourden gauge used to charge inductance for telemetering.

Skin temperature in flight.

They insert into the skin small patches of metal of known melting point. These patches are each connected to an electrical circuit which sent a signal when the metal melted.

(Schuler was only concerned with instruments for the power unit)

Tank Contents and Fuel Flow.

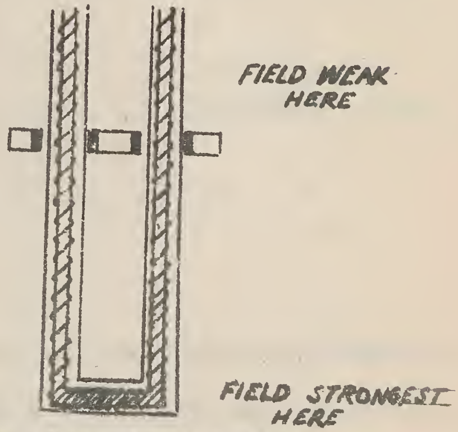
The first methods of measuring fuel consumption was by a continuous reading depth gauge in both tanks. (On the combustion chamber test bed, they measured the fuel consumption by feeding from weigh tanks)

(1) (Contimuous) - Cylindrical condenser probe. Two concentric cylinders (aluminum) used with condensor bridge measuring system. Very good with $L.O_2$ as dielectric constant was constant. $L.O_2$ an excellent insulator. Not too successful with alcohol but they anodised the surface of the aluminum

tube. One of these probes was built into each tank of every rocket due for test. To mount the cylinders, plexiglass was good for $L.O_2$. With care, 1½% accuracy. Made a more elaborate bridge but never used as this system was abandoned.

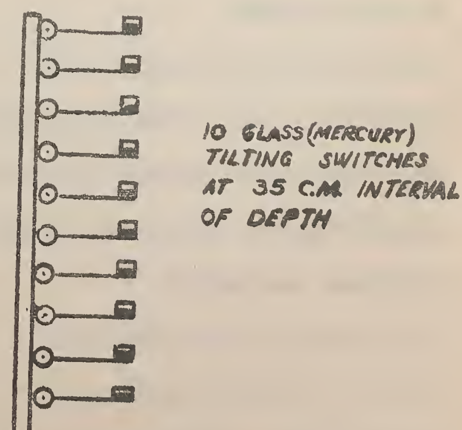
Depth Gauge - System 2.

Developed by Professor Hase of Hanover. Gave a straight line curve. O.K. for alcohol. No good for $L.O_2$ due to temp. variation. Iron U wound with wire. Strongest field at bottom. Each leg sheathed in porcelain tube. This constituted the Primary of the inductive system. The secondary consisted of a shorted turn of aluminum sleeves in a glass float. 1% accuracy on alcohol. Wanted ½%, but could not get this with these continuous instruments so changed to two new instruments giving signals at 10 levels.



System 3 - for Alcohol.

This system sometimes used with the continuous system. Accuracy 2/1000. L.O. pumped in always 4000 litres error on top tube contact. Never greater than plus or minus 8 litres.



Depth Gauge

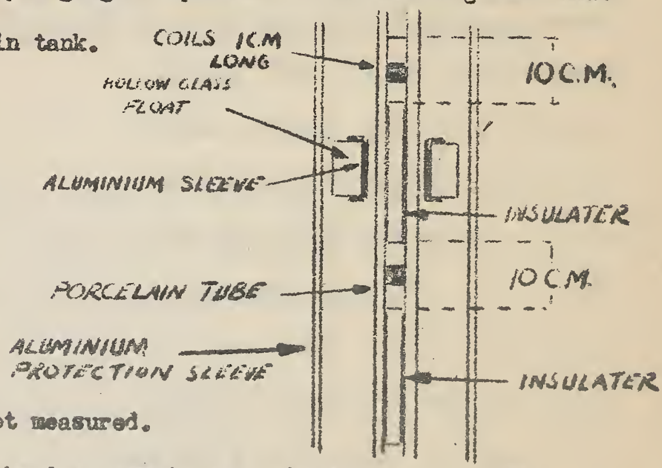
System 4 for LO_2

Substituted for the 10 mercury glass switches floats rotating a small wheel with make and brake contact.

System 5.

Discontinuous electro magnetic depth gauge. Impulse to indicate as glass float passed each coil. 8 - 10 coils in tank.

Used for Wasserfall.



In TAIFUN the fluid flows were not measured.

For testing Wasserfall, most of the instruments were the same as for A4.

However the electrical insulation which was O.K. for alcohol was no good for Nitric or Visol.

For acid use insulator "Dynagen" (Opanol) use a different insulator for VISOL.

For Wasserfall did not use the capacity tube or the CAPACIty tube or the LO2 float and wheel system.

Nitric attacked mercury switches - poor contact so used system 5 - see above.

Difficult to use. Tank depth gauges over short runs so developed flow meters.

Used normal choke plates and pressure drop measuring devices for acid and alcohol but for LO_2 had to design special venturi to avoid turbulence and fusing.

Very critical to measure your pressure in the right places.

Use big holes. Normal size 2 - 8 mm but for $L.O_2$ 5-8 mm to avoid errors due to boiling.

They used this type successfully for liquid oxygen.

<u>General.</u>

Was intended to move combustion chamber. Best boys to LEHESTEN near SALFELD.

Depth gauges at first one was built into every A4 for experimental purposes

When in production

(A) 1 in 10

thru (B) 1 in 20.

then abandoned.

J.I. and GJG.

Interrogation of ERICH SEIFERT, interviewed Garmisch on 22 May 1945, by H.A. Leibhafsky and G.J. Gollin

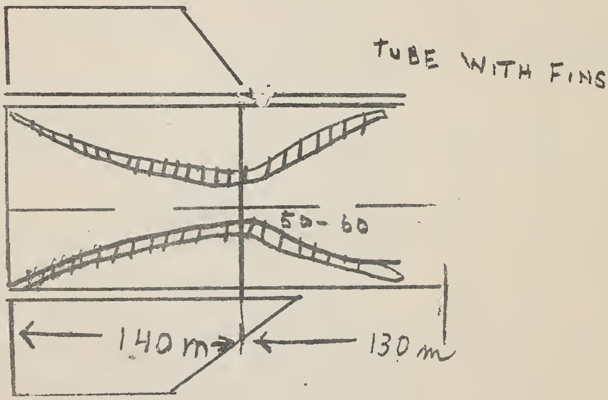
Made jigs and dies.

1. **TAIFUN** (see illustration below)

dia 100 mm. length about 6 meters. combustion chamber 13" to long. Mild steel 1 mm mostly, 2 1/2 to 3 mm at the thickest. Sprayer in 3 parts, many holes. Tanks 1 mm wall. Fuel tanks about 1.2 metres long. Inner tank about 60 mm dia? Probably samples at Blecherode. Tried all kinds of stabilizing fins, some short and some long.

2. **Wasserfall**

Worked on middle part of the body.



Interrogation of FRITZ SAHR, at Garmisch on 22 May 1945 by H.A.Liebhafsky and G.J. Gollin.

Concerned with the liquid oxygen plant at Peenemünde.

Rail waggons 22,000 kg contents
Road waggons 6,000 - 8,000 kilo

Insulation 30 cms of "magnesium"powder

Fixed Peenemünde LO_2 factory

Storage -- 2 tanks 50,000 kilo each, suspended from an iron frame, insulation magnesium powder.

2 compressors each 2 cylinders. Each compressor [redacted] made 500 - 600 kilo of LO_2 per hour.

Interview with Dr. Reinhod Strobel (of Peenemunde)

Garmisch Partenkirchen, May 18, 1945.

Interrogator: Dr. F. Zwicky.

Dr. Strobel formulated the ballistic problems of the V2 which were to be solved mathematically by the Institute of Applied Mathematics (Prof. Walter in Darmstadt).

The Peenemunde windtunnels (now at Kochl) under the direction of Messrs. Hermann, Kurzweg, Wegener) and others, as well as the wind tunnel in Aachen (Wieselsberger) supplied the basic physical and aerodynamic data for all of the ballistic calculations. The meteorological service of the Reich supplied the data concerning the atmosphere, such as temperatures, densities, wind velocities etc. as function of the altitude.

The dispersion in range of the V2 (50% zone) happens to be a circle (accidentally), for the unguided missile. The diameter of this circle is 4.5 km. For the radio directed V2 the lateral dispersion is cut down to one half and the 50% dispersion zone is an ellipse with a major diameter of 4.5 km in the direction of flight and a lateral minor axis of 2 km. The diameter of the 50% dispersion zone is calculated from the least square formula

$$x_{50} = \pm 0.6745 \sqrt{(\Sigma \Delta x^2)/(n-1)}$$

The dispersion has its origin in the following errors:

1) Errors in the maximum velocity reached because of erroneous timing of the cut off of the propellants (Brennschluss).

2) Errors in the distance travelled at the time of the propellant cut off.

3) Abgangswinkelfehler (Error in the angle relative to the vertical at the "Brennschluss" or the start of the free trajectory.

4) Abschaltzeitfehler (Error in the timing of the pro pellant cut off.

5) Atmospheric fluctuations, influence on the drag (drag coefficient C_w). These fluctuations were not mathematically considered.

6) Weight fluctuations relative to the thrust was also taken into account.

Formulae were established for the change in range in dependance of the changes of various characteristic parameters. These formulae gave the development engineers the proper leads on how to change the various parameters of the V2 in order to achieve the largest range. In this way the weight was reduced as far as possible.

Individual orbits were analyzed. The orbits were surveyed and from known weight and acceleration the thrust as a function of time could be determined for the individual orbits. From the data on the propellant cut off the range was then computed and compared with the actually observed range. The two ranges usually agreed within an accuracy of less than plus or minus 1 km. With head wind and tail wind additional changes of the range result. Theoretically a constant head wind of one meter per second shortens the range by ten meters. Since sometimes wind velocities of 40 to 50 meters per second were observed changes in range of the order of 500 meters could be attributed to this cause.

Influence of the jet on the drag coefficient C_w

We write for the total drag

$$W = C_w \frac{\rho}{2} V F \qquad F = \text{CROSS-SECTION}$$

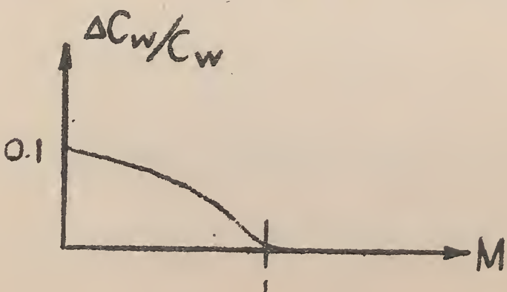
The drag on the missile is greater when the jet is on.

For Mach numbers smaller than unity

$$\Delta C_w (\text{MAX}) \cong 0.1\, C_w$$

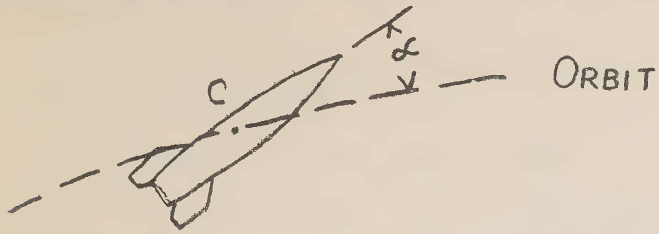
$$\Delta C_w \cong 0 \quad \text{for } M > 1$$

The qualitative diagram is as follows



Azimuth Errors. (Ask Drs. Rosental, Steinhof, Holzer)

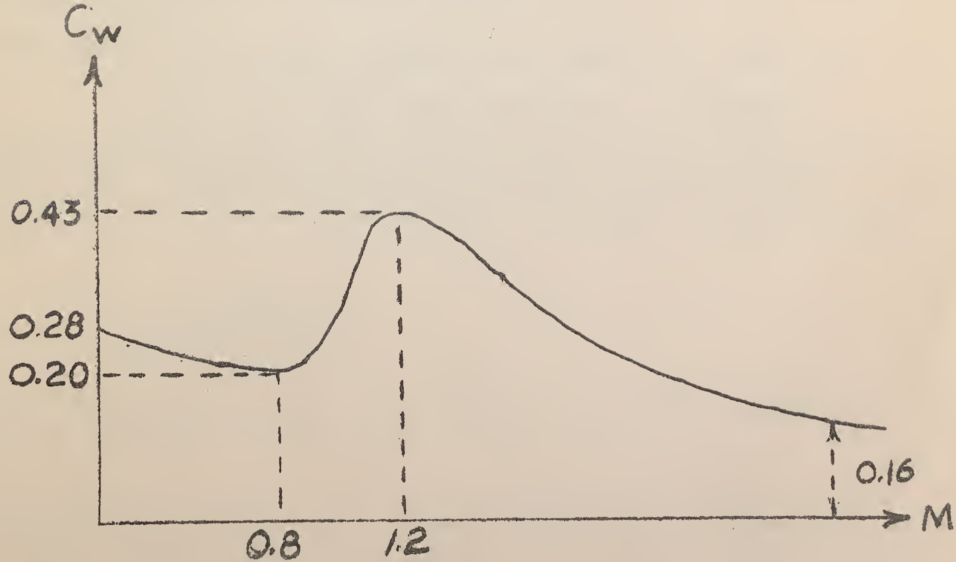
Oscillations of the missile around its center of gravity.

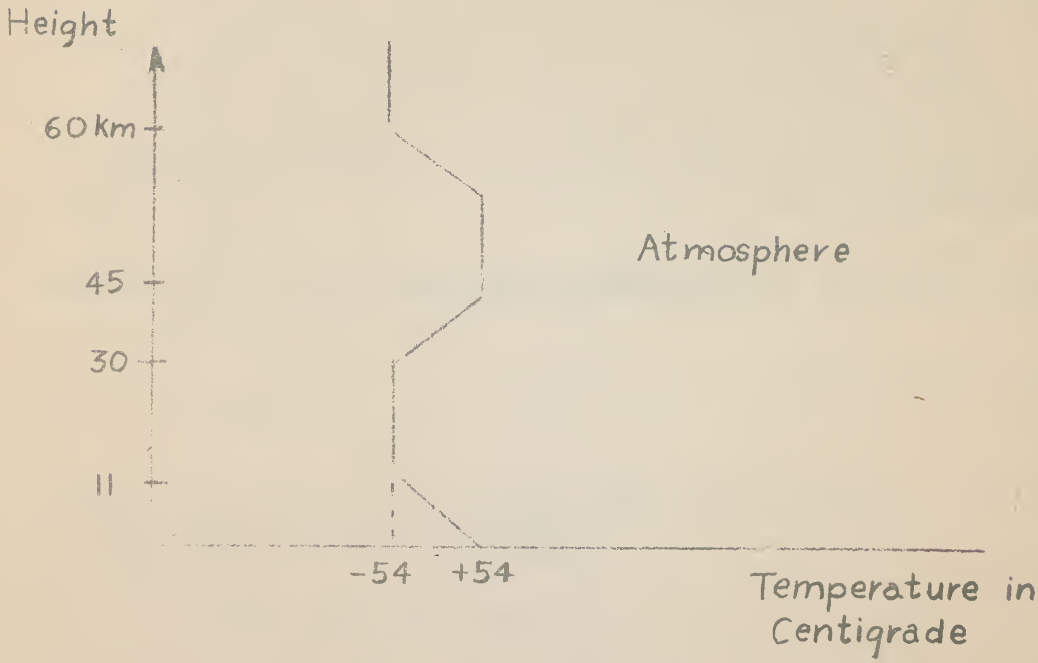


The angle of attack at the time of the propellant cut off is different for different actual orbits. The drag coefficient depends on this angle.

As a function of Mach's number M the drag coefficient C_W or C_D has a maximum at M = 1.2 which is C_W (max) = 0.43

DRAG COEFFICIENT FOR V_2




Height
60 Km
45
30
11
Atmosphere
-54
+54
Temperature in Centigrade

The problem of the influence of long mean free paths on C_W at great altitudes was not considered by the Peenemunde Group.

Recently when many V2's were fired many temporary problems occupied the whole attention of the aerodynamicist at Peenemunde and the more basic investigations were turned over to the Darmstadt mathematical group.

For the aerodynamics of the wing born missiles at Peenemunde interview Dipl. Ing. Geissler.

Optical triangulation of the orbit of the V2.

A base line with at least three observation stations was used and observations made in clear weather both by day and by night. Specialist in this field is Dr. Helmut Schmid.

Electrical survey of the path of the V2.

This was done with short waves on the basis of the Doppler principle. The ground frequency emitted from the ground station was reemitted from the missile and arrived at the various ground stations as a changed frequency, the change in frequency representing directly velocity components of the missile. Very good results were obtained with this method, because one obtains in this way the velocity directly rather than by differentiation of the path as in the optical method.

Brennschluss = propellant cut off.

a) Brennschluss through radio signal with an accuracy of dispersion in the maximum velocity equal to plus or minus one meter per second.

b) Brennschluss through the use of integration devices.

In this case the acceleration is integrated. For integration device see the interview with Prof. Buchhold in London. With this apparatus the acceleration of gravity enters the picture also. There may therefore occur a rather large Schub - Zeit Fehler (Thrust time error). On these errors interview

Dr. Kirchstein
Dr. Schwidewski
Dipl. Ing. Horn

The tests at Peenemunde include 50% of the cut off's of the type a and 50% of the cut off's of the type b.

The missiles which were sent against England used the cut off b) in 90% of the cases and only 10% of cut off's of the type a. The reason for this is that the crew did not care to stand around and operate the radio equipment because of danger of air attacks.

In addition there were not enough of the electrical ground in-stallations available.

Improvements in the "Treffsicherheit" (Accuracy of firing)

a) Improvement through corrections of the path. This involved the development of a double integration from the ac-celeration to the distance travelled. (Interview Dr. Kirsch on this)

b) Correction of the timing of the propellant cut off. This latter method is less accurate than a).

Both methods are based on the following idea. One corrects the velocity near the time of propellant cut off either after com-paring the distance travelled or the time on reaching a definite velocity with the distance or time theoretically expected. These methods however were in the process of development. Actual firings were so far only corrected with the time correction method but not yet with the distance correction method.

The time correction method is less accurate than the distance correction method because it involves only one point on the path (with no knowledge of previous history), while the distance cor-rection method involves the whole path. For instance if the time observed at the cut off is the normal theoretically expected time and the velocity at cut off the prescribed theoretical normal velocity then not necessarily actual distance travelled equal normal theoretical expected distance.

1. Miscellany:

The V2 charges up electrically to order of magnitude 20,000 Volts at the start of the run and at the propellant cut-off. During good combustion there is no charge and previously built up potentials disappear. The net charge on the device must be due to solid particles in the combustion gases. The existence of solid particles, either from the combustion orfrom dust particles from the outside air is necessary in orderfor the bombs to be charged up electrically.

2. Errors in range of the V2.

The 50% dispersion zone refers to V2 bombs which all are in good order. There were of course many systematic failures which account for the actually observed wide scattering in the range.

3. Double integration of the acceleration.

A contract was given Prof. Buchhold in Darmstadt to develope such a device, which was intended for connection of the path at the time of the propellant cut-off. A proposal was made for activation with the acceleration integrator, of a motor, the angular velocity of which would always be proportional to the velocity V of the projectile. The number of revolutions of this motor would be automatically counted and thus give the distance travelled by the projectile.

4. Azimuth errors for the V2.

Azimutal line up of the V2 on the firing platform was possible within one to three "artillery divisions" (Artilleriestrich = 1/6400 of the circle). This error accounts at most for one kilometer lateral scattering. Ordinary artillery triangulation instruments were used to adjust the projectile on the table. The plane of the flight orbit is defined by gyros to about the same accuracy in final range dispersion as corresponds to the error in azimuthal line up.

5. Damping of the oscillations of the V2.

In the beginning inaccuracies in the construction of the V2 played a great role. These inaccuracies resulted in an angular velocity around the axis of the projectile of about 30-60 rpm. Later on the generation of angular momentum during the flight was more and more eliminated. The control problem with the V2 is much more difficult than with ordinary aircraft where stability must be achieved only in a much more limited velocity range (1 to 6). No artificial damping is used in the V2. Rather the air itself is used as the damping medium in such a way that both the rudders in the jet and the external ones are made to anticipate the oncoming oscillations and are moved in such a fashion as to compensate them in statu nascendi.

6. <u>Maximum stagnation pressure P_s</u>

Upwards flight P_s (max) = 1.1 stu

Downwards dive P_s (max) = 5.5 stu

<u>Heating of the skin of the V2</u>

Experimental law for the friction temperature T_F is

$$T_F = V^2 / 2000 \text{ in Centigrades}$$

where the velocity V is to be expressed in meters per second. The dependence of on various variables has not yet been determined accurately.

Interview 19 May 1945

INTERROGATION REPORT OF DR. STE..OFF - 30 May 1945.

By Dr. R.A. Sharpe
Interpreter- Dr. Rosenthal (Peenemunde)

The purpose of the interrogation was to obtain information on Code names used in connection with A4 Radio Equipment. Code names were allocated by Peenemunde to all complete equipment! In all correspondencee individual units were only refered to as an item of a code named equipment. These code names did not appear on the manufactured equipment which was only marked with a type number. These type numbers were sent to the manufacturing firms by the Ministry concerned and not from or through PeenemÜnde. There would therefore be no one available that would know the numbers concerned!

The following code names were obtained:

1. Equipment in Rocket

Honneff: This name covered the control signal receiver and auxilliary units mounted on the same main frame.

U.K.E /7: This name covered the receiving equipment for the Leitstrahl beam signals.

Messina I: Was the code name given to the ~~xxxxxxxxxxxx~~ Telemetering equipment including transmitter, modulators etc.

Papergie : This was a self oscillating Radio Receiver which was used as a low power transmitter for field strength measurements in connectionwith measurements of absorption of Radio Waves by the rocket flame. It was used only for experimental purposes!

Ortler : This name covered the Verdoppler Receiver Transmitter in the rocket.

FU 4/V11 : This was the name for a receiver designed to provide a number of radiocontrol channels to the rocket. It was used for research purposes only.

I. GerÄt I or II : Was a general name for Integrating Accelerometers. Iller GerAt was known as I Gerat I and Isar GerAt as I GerAt II.

The following terms are noted. These were not code names:

Oernig- is used generally for a power unit.

Haupt Verteiler- for a junction box.

Antenna Kasten- for an antenna matching unit.

2. Test Equipment for Rocket.

The ground equipment used for testing the rocket is covered by the general name R-Gestelle. This Gestelle or frame contains a number of units. It contains a low power transmitter and modulator for producing signals similar to those obtained from the Leitstrahl Beam and also a Zoi lestein Sender for testing the

Verdoppler. Several units that are probably B-Gestellen were found in the train at Lieting. The units in the frame were numbered so that an individual unit is known as Unit No- of B.-Gestellen.

3. Ground Equipment

Hase : This code name covers the Leitstrahl transmitter and aerial switching unit.

Hawai- I.b : This name covered the complete ground equipment for the Leitstrahl beam including Diesel Generator Unit, Modulator etc.

Cololenz : This was the code name given toa monitering receiving equipment located near the firing site for checking the direction of the Leitstrahl Beam.

Neaple : This is the ground transmitter for the Verdoffler system.

Z-Gestell : This covers the Verdoppler receiver and all the units for the Doffler velocity measurements. It includes the receiver, mixer unit, filter unit and Frequency Bridge with automatic operating circuits.

Palermo : This was the code name for the transmitter used for the sending the control signals.

Heide : This was the code namefor the modulator used with Palermo.

Dr. Steinhoff:

Dr. Steinhoff was asked for information on the effect of the exhaust gases on radio communication with rockets. He stated that the work carried out by Prof. Vieweg on the properties of jets had been brought to an end as the results indicated that interference due to this cause would not be sufficient to cause trouble with A-4.

The main conclusion from Prof. Vieweg's work was that interferense only appeared when solid particles were present in the gas. Interference was caused by electrical charges on the missile, but this was not sufficient to cause trouble as it was small compared with the field strength produced by the controlling transmitter at the maximum range. Dr. Steinhoff stated that no tests on radio absorption by the jet had been made on the test stands but all tests had been made in flight. The field strength at the missile had been continuously telemetered to the ground and recorded against height. The field strengths recorded were then compared with calculated field strengths assuming no absorption.

At the 50 mc/s frequency used on A-4, absorptions of as much as 90% had been measured. The measurements of absorption had agreed with theoretical values to within 5%. Most of the work on this part of the problem had been carried out at Gratz.

There is a definite relation between the electric charge on the missile and the presence of particles in the gas stream. If there is absorption due to the presence of particles, the absorption is proportional to the electric charge. Complete combustion gives less particles and less absorption. Dr. Steinhoff did not know of anything that could be done to the fuel to reduce this trouble, and he had not heard of any experiments that had been carried out to investigate the possibilities of adding substances to the fuel to reduce this trouble.

A-4 charged up to a voltage of 25,000 at the beginning and end of combustion, but the value was smaller during combustion.

No trouble was anticipated with Wasserfall due to absorption or interference as the ranges were shorter than A-4.

Wasserfall.

Dr. Steinhoff started work on Wasserfall in November 1942. He had hoped that Wasserfall would be ready for use in November 1945. This however would only have steering by an operator with tracking of the missile by optical means. At night, this would be used in conjunction with illumination of the target by searchlights.

Electrical Propulsion.

About 4 or 5 years ago, Peenemünde was interested in electric rocket propulsion. It was, however, only in the research stage. Dr. Teil had been the liaison officer between Peenemünde and this work. After he was killed, in the RAF raid, nobody had been appointed in his place.

The principle worker in this field had been Prof. Heisenburg in Berlin. In 1941, which was the last occasion on which Dr. Steinhoff had had information on this subject, the equipment had been considered to be of practical use for road vehicles and submarines.

The design had been more suitable for the production of small powers for long periods than for large powers for short periods required for rockets.

Dr. Steinhoff.
Herr. Holzer.

1. Dr. Steinhoff stated that he had not done work on the Y Gerate system of automatic control. This had been developed by Plendl. However, when he started work on the A-4 project, he investigated the then existing Y Gerate equipment with a view to its use. He soon came to the conclusion, however, that this system was not of sufficient accuracy for the control of projectiles and work was started to improve the system. These improvements produced a beam which gave a stated accuracy of control of plus or minus 20 meters at a range of 140 K Meters from the transmitter. All early tests of the control equipment were carried out in an aircraft and it was pointed out by Dr. Steinhoff that this figure represented maximum error in flight path of the controlled aircraft and not the dead area of the beam. This appears to be an extremely high degree of accuracy to achieve with a beam system on a frequency of 50 mc/s, but Dr. Steinhoff was very definite about this figure.

2. The first tests were carried out using the radio equipment in a Heinkel 111 aircraft fitted with a Siemens K4U automatic pilot. The automatic pilot was later changed for an improved type. Correctly banked turns were used. The results of these tests of automatic control of an aircraft are of interest in connection with the work now proceeding in both U.S. and U.K. on automatic approach and landing of aircraft. The beam was assumed parallel and the constants of the system were fixed at the best compromise values which were obtained mainly as a result of experiment. It was necessary to switch on the automatic control with the aircraft in the beam and with its heading correct to within 1 degree. With this arrangement, the aircraft would fly from about 200 K Meters to about 3 K Meters from the transmitter. However, the latter part of the flight was only successful if there was no change in cross wind during the approach. Most of this aircraft work was carried out in 1940.

3. Radio tests in an A-5 were carried out in 1941. Much trouble was encountered in trying to find suitable constants for the control system because of the very large speed range involved. Successful control had not been achieved when the A-5 was abandoned in favor of the A-4.

it has only been found possible to apply a very small degree of control to A-4, otherwise the system became unstable.

4. Both the ground and rocket radio control equipment had been developed by Lorenz, Berlin, to a specification of requirements from Peenemunde. Mr. Holzer was later interrogated on certain details of the above subjects but was very unwilling to speak of any experiences they had had during development.

Interviewed 19 May 1945.

Bernhard Teszmann
1st Engineer
Age -32
EW23

Partenkirchen 16 May 1945

I, Bernhard Teszmann, was born on the 15th of August 1912, the son of a sculptor and plasterer, Robert Teszmann of Zingst on the Baltic, Kreis Franzberg, Barth. Shortly before the outbreak of the 1st World War, my parents moved to Berlin. Here, I attended No. 9 Grade School from my 6th year (from October 1918 to the end of September 1926). Under the pressure of the post war conditions, it was impossible for me and my three brothers and sisters to go further with a higher education. However, my wish was to become an engineer. At the completion of my schooling, I became a locksmith and apprentice artist with the firm, Orenstein and Kopple, in Berlin. During this time, on my own time and money, I visited the City Trade Building in Berlin, in order to prepare myself for entry into a higher machine construction school. With the completion of my apprenticeship in 1930, I completed my final examinations at the Trade Building and went still further into the studies of a machine construction engineer in the Higher Machine Construction School, Berlin (Max Eydt). In the beginning, for many days, I worked as a technician; later, as an independent designer with my apprenticeship firm, Orenstein and Kopple in the division of dredging machinery and crane construction as well as locomotive engines and engine construction. After two years activity, (I still did not have my Engineering Degree). I received, in the division of dredging machinery and crane construction, an independent work group. in which I primarily supervised all the moving mechanism, and all machinery employing leverage and special operational arrangements. Later, and in between, I carried out designs and calculations for large base plates for electric and steam driven dredges as well as for separate machinery parts. Before I left the above mentioned firm, (in November 1935), I worked 1½ years on situation plans for large construction installations, the means of appropriate estimations of different types of dredging machines, with the additional calculation of daily and hourly work output and individual technical statements, which were rec ired as a service to our customers. In August 1935, I passed my state admittance engineers final examination, after a school attendance of ten semesters (5 years). After this examination, I met Doctor von Braun (now Professor Dr. v. Braun) at the school, in order to work on the subjects of rocket development, at that time a small work union. I started work at the artillery range near Kummersdorf on the 18th of November 1935. The service position was attached to the OKH Heereswaffenamt. Above all, I was here as a designer for the jet propulsion oven of 300 Kg and 100 Kg thrust, also for small armatures and piping arrangements, which had already undergone a minor test run.

The present ground and the existing installations in Kummersdorf were too small for rocket development. so the associates of Peenemunde elected to move to the Usedom/Ostsee Island for the planning work.

In the middle of the year 1936, Prof. v. Braun commissioned me with the planning work of small and large test benches, so that I was ordered by the air force to have a construction directive already established after the preliminary work in 1936. Under my influence, and according to my original statement, in conjunction with heavy construction firms like Wiemer & Frachte, Berlin; Beton & Monierbau, Stettin; Gallnow & Son, Stettin; Machine Factory Goede, Rehfelde; R.O. Meyer, Hamburg; and others who were to supply necessary test stands for testing R-tanks, complete apparatus, and steam and pump assemblies. My duties also included the arrangement and furnishing of all test stands, i.e. designing of steel runways, the establishing of conduits and valve arrangements, as well as the supervision of erections undertaken by different firms. The same applied to the field testing at the subsidiary station Raderach near Friedrichshafen on Lake Constance, and Vorwerk Mitte in Lehesten near Saalfeld/Thuringen.

To complete the above mentioned work, I had a work staff of 30 to 35 men at my disposal --- engineers, designers, and technical draftsmen.

Up to this time, I was with the OKH Testing Station at Peenemunde; later with the OKH Heereswaffenamt, Peenemunde.

WEIRER HANS Dr. Ing. Prof. No 412.

Army Service. Was Professor at Technical High School at Gratz until 1941 when he was called up for the army. In the army, was in charge of an MT Maintenance section in Russia and North Norway, attached to an acoustic range finder for artillery (known as an observation troop). He went from Murmansk to Peenemunde in April 1943. He had a special commission in the army with no rank.

Work at Peenemunde: He is in charge of a group of 30 to 50 men engaged in carrying out field tests on A4. New equipment was sent to this group for field trial. They however knew nothing about the design details of the apparatus tested but were only interested in its performance.
This group was also regarded as a training unit as people were transferred from the group to firing sites.
Weirer has little knowledge of radio.
Attached is a layout drawing of the layout of A4 firing sites, drawn by Prof. Weirer.

Prof. Dr. Hans Wierer. O.U. 16 May 1945

1. I was born on the 7th day of February 1902 in Soldbad Hall in Tirol. My father was Johann Wierer. He was a teacher at the local school for woodcraft.

2. After I completed Public School, I went to grammer school at Soldbad Hall in Tirol also to Mehreran by Bregenz on the Bodensee and in Innsbrück. I completed my high school at Kufstein, Tirol, with honors. In November 1921, I enrolled at the Technical High School in Munich. I studied electrotechnic and during my time off, worked in several mechanical workshops, particularly in electrical power houses. I completed my studies at the Technical High School in Munich in July 1925 with very high honors. I completed my Doctor studies during my industrial work, and I also wrote at the time a thesis on "The Electromechanical control of high tension networks" which I passed with honors at the Technical High School, Vienna.

3. After I completed my studies in Munich and due to the lack of work in the Austrian Electric Industry, I went to Berlin, and in August 1925, went to work for the Bergmann-Electro-Works A.G. where I worked in the central power plant. My duties were to study projects for power plants, tension, and transformers. Besides that, I was to concentrate on blind performance control and voltage. On the 1st of October 1928, I left the Bergmann-Electric Works and went to work for the Siemens-Schuckert-Works A.G. in Berlin-Siemenstadt. Again I worked in the central power department. I was to solve the problem of a long distance high tension power line. (220 kv from Brauweiler near Cologne, to Bludenz on the Voralberg). In 1929, I was sent to the Siemens-Relais-Corporation. My problem was to scleve the distribution of automatic and remote control of power stations of all kinds and industrial installations. I also worked in building all kinds of apparatus necessary for this project. I worked extensively on the construction of sub-power stations, to be used as reserves for high tension networks. I also made installations for powerful hydraulic pumps to be used in place of the networks, should it become necessary. I also installed apparatus in great and small power plants for remote control.

My problem was also to see that the industrial sections were supplied with electric power at all times. I also had to manage work programs. So far I had no connection with any weapons techniques. Towards the end of my work with the Siemenswerke, I specialized on an adjuster which would replace the old rotating number adjuster. This work, however, was terminated due to the outbreak of the war.

4. In 1940, I received a call from the Technical High School in Graz, so I left the Siemenswerke and took over the professorship for "electro-installation". But, it was only for a short while, for in April 1941, I was drafted into the army with the rank of troop-engineer. (War Administration Board). Afterwards, I was made sound engineer in an observation battalion. On the 20th April 1941, I was transferred to the experimental army ordnance station Nord (VKN) Peenemünde. At the Electro-Mechanical-Works, formerly "HAP" (Heimat-Artillerie-Park Karlshagen) due to my practical experience I was given the leadership in the department for airborne installation and ground networks. I hold this same position now. It is my job to see that the different parts and implement

Dr. Wierer.

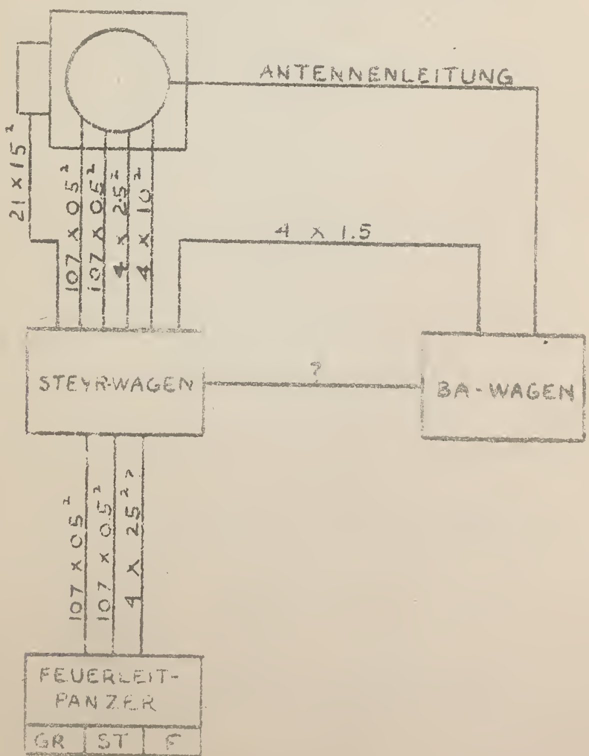
Vehicles used for electrical and radio gear at operational shoots of A-4.

1. Steyrwagen. - This has replaced the Struever Wagen, and performs the same functions. It contains the electrical generator and the relays connecting the control vehicle with the rocket circuits.

2. Feuerleitpanzer (auch Kommandopanzer genannt). Light armored vehicle (1 cm armor) containing three control panels. (Control, driving mechanism, radio).

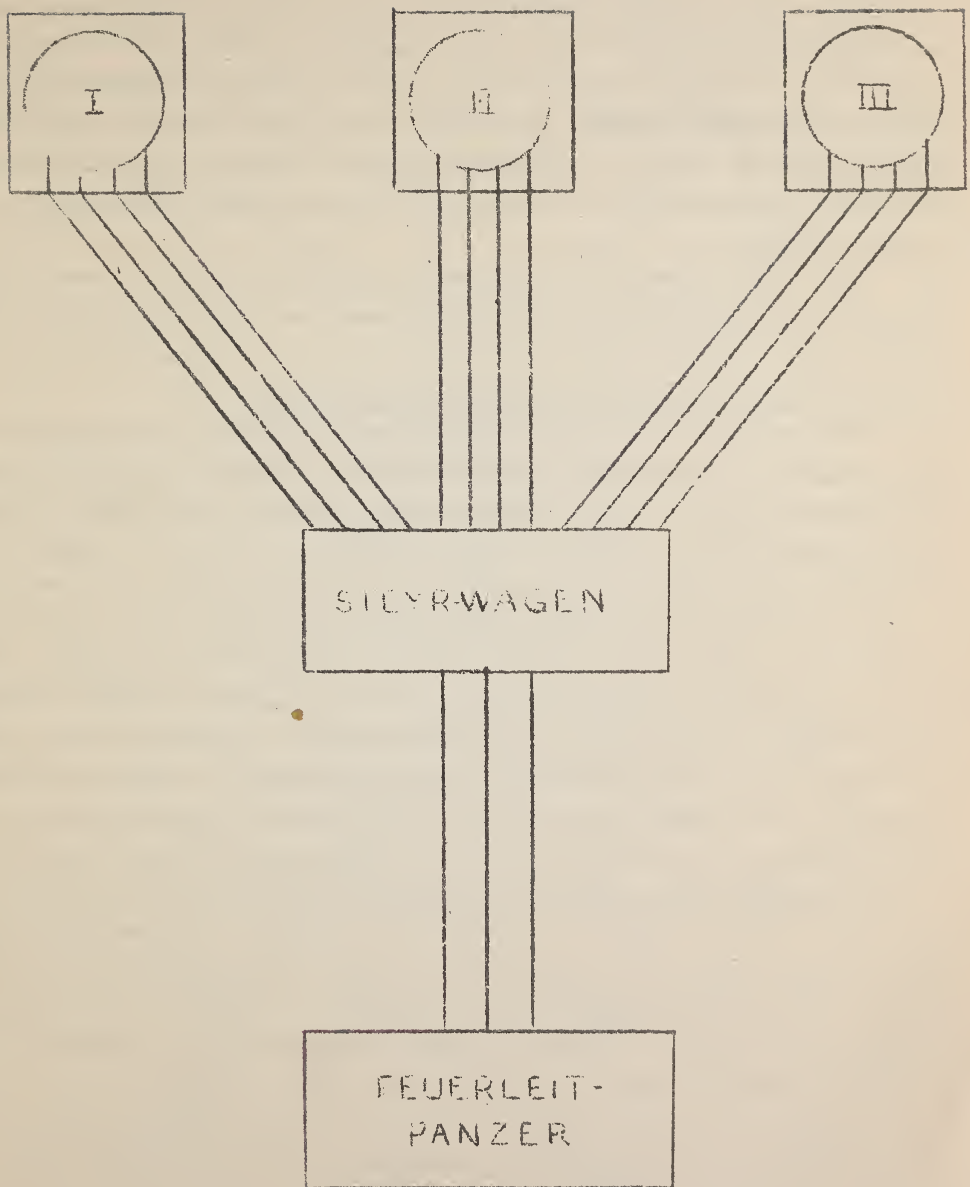
3. BA Wagen. Radio testing apparatus and instruments for trajectory measurements.

4. Trailer carrying cable drums.



of the apparatus are properly connected. The preparations for the ground installation were very extensive also, which were used not only for the testing of different parts and apparatus, but also for the diring mechanism. It was also difficult to solve the problem of supplying enough current for the airborne and ground installations. The three main problems were: The quick testing of all apparatus in the factory as well as by the troops. The safe and sure firing of the projectile and the workability of the ground networks, so there would be no disturbances which would either damage the apparatus or make the projectile miss the target. It was also the duty of my department to make the electrical tests on all testing stands.

Signed: H. Wierer.


I
II
III
STEYR-WAGEN
FEUERLEIT-
PANZER

INTERROGATION OF DR. [illegible] WEISS, 11 June 1945. at Garmisch
By: C.H.Smith and Lt. (jg) [illegible] Wilkinson.

Dr. Weiss stated that Prof. Gladenbeck, in mid 1944, had been appointed coordinator of all the numerous homing or target seeking systems. The title of the job was B d F or Bevollmäachtigte für Fernsteuerungsforschung. (It may also be noted here that Gen. Dornberger had stated in a previous interview that in Jan. 1945 this job had been turned over to him in addition to the coordination of all rocket work)

Dr. Weiss's work on automatic target seeking systems fell naturally into two general classes: 1) for ground to plane missiles, and in particular the Wasserfall and 2) for plane to plane missiles, as the X-4.

TARGET SEEKING EQUIPMENT FOR GROUND TO PLANE:

The initial phase of the work on Wasserfall contemplated launching in a vertical direction and by means of tracking devices, which could be either optical or radar, bringing the missile into line of sight course with respect to the target. Two tracking devices are thus required, one tracking the target and one tracking the missile. A remote control system operating in conjunction with a computer and indicator makes it possible to bring the missile onto a line of sight course. When the missile gets within the operating range of the automatic target seeking equipment this equipment should take over and control the missile on a constant bearing course into collision with the target. Several methods of bringing the homing system onto the target, or getting the target within the 6 degree field of view of the homing system were considered. This general problem was known as Brücke. Of the several types of homing systems considered, it was decided to attempt a constant bearing system. Other types would of course be either one in which the axis of the homing device was coincident with the axis of the missile or one in which the axis of the homing device was maintained in the direction of the flight path, or windstream.

Early in the game it was recognized that use of a line of sight course resulted in the latter portion of the trajectory in a fairly close approximation to a constant bearing course. The closer the missile gets to the target the nearer the approximation holds. This fact can perhaps be understood by noting that at a great distance from the [illegible] point successive positions of the line of sight path are nearly parallel. Now if the homing device can by some means be directed to bring the target within its field of view it will be automatically set up on a collision course with the correct lead angle.

Krücke A the first attempt at accomplishing this consisted of transmitting from the ground a radio signal (in the neighborhood of 3 meters wavelength) a receiver in the missile operating from two antennas and operating on a phase difference direction ~~finding~~ principle binding turned the axis of the homing system in the direction of the incident waves. See Fig. 1. To eliminate the undesirable effect of the unavoidable yaw of the missile during control it was necessary to provide a reference of the flight path of the missile by means of a vane in the windstream very similar to a weathercock. Once within the operating range of the homing device error voltages from this device operated the control surfaces through a computer so as to adjust the flight path in such a manner as to restore error with respect to the reference line from launching point to target. A number of difficulties soon became apparent which resulted in the eventual abandonment of this system. Among these were: 1) antenna size due to length of waves used and 2) inaccuracies resulting from deformation of the wave front due to ionized gasses of propellant. (With respect to the 2nd difficulty, theoretical computations resulted in the conclusion that it was impossible to obtain the desired accuracy of 0.1 degree in the presence of the ionized gasses. With the use of cm waves better accuracy was expected but it was still computed that the desired accuracy could not be obtained.) In order to get around these difficulties two methods were considered; these were known as Krücke B. Both of these methods were designed around the idea of a gyro-stabilized platform in the missile. ~~[illegible]~~

Krücke B: (first method)

This method contemplated a gyro platform in the missile, set prior to launching to be parallel to the ground plane, uncaged before launching or while the missile was still in vertical flight so that the orientation of the ground plane would be preserved fro reference within the missile during its entire flight.

The angle of the line of sight between launching point and target relative to the ground plane is available on the ground from the tracking device, be it optical or radar. If this angular information is transmitted to the missile and the missile has contained within itself a gyro stabilized platform preserving the ground reference plane, the angular information transmitted can be used to position the axis of the homing device relative to the reference plane and thus point the axis of the homing device in the same direction as the line of sight path or toward the target. At the time the homing device takes over, the transmission from the ground ceases and the latest position of the axis of the homing device relative to the gyrostabilized ground plane is retained. See Fig. 2. Error information derived from the homing device directly actuates the control surfaces through a computer so as to correct the flight path of the missile to zero error of the homing device. This results in a constant bearing course to the target as it demands a missile flight path which results in a bearing line from missile to target whose direction is fixed in space. This is a neat solution of a rather old principle. However disadvantages are present, chiefly in the size and complexity of equipment in the missile.

<u>Fricke B:</u> (second method)

This method also uses gyro-stabilization but in a different manner. See Fig 4. A platform at the ground station is made to follow the motion of the ground equipment which is tracking the target. The perpendicular to the plane of the platform is thus always directed toward the target. Upon the platform are mounted two gyros, each with their spin axes initially in the same direction as the perpendicular to the plane of the platform. The gyros have only two degrees of freedom which is the same thing as saying that the outer gimbal is rigidly fixed to the platform. Also the direction of constraint of the two gyros are mutually perpendicular. Pickoffs are provided on these two gyros such that the angular position of the platform relative to the gyros is given in the form of two angular components. This information is transmitted by a pulse radio control system on approximately a 2 meter wavelength. The final control system had not been determined but a tentative system based on 4 separate f.f. channels was to be used in initial development. The missile is also provided with a similar platform and gyro system. See Fig 3. Now if the platforms and gyros in the missile and on the ground are orientated in the same position prior to launching, and transmission of angular information is continuous the platform in the missile then driven by motors which move the platform relative to the gyros, will always have its perpendicular device has its axis rigidly affixed to the platform and coaxial with the perpendicular to the platform.

As soon as the homing system becomes operative, transmission from the ground ceases. The latest position of the axis of the homing system is stabilized in space. Pickoffs from the platform in the form of Cartesian coordinates furnish a reference from which the homing system operates. As before, error information from the homing device is used to actuate the control surfaces thou a computor in such a manner as to adjust the flight path to restore zero error in the homing system. This again results in a constant bearing course to the target.

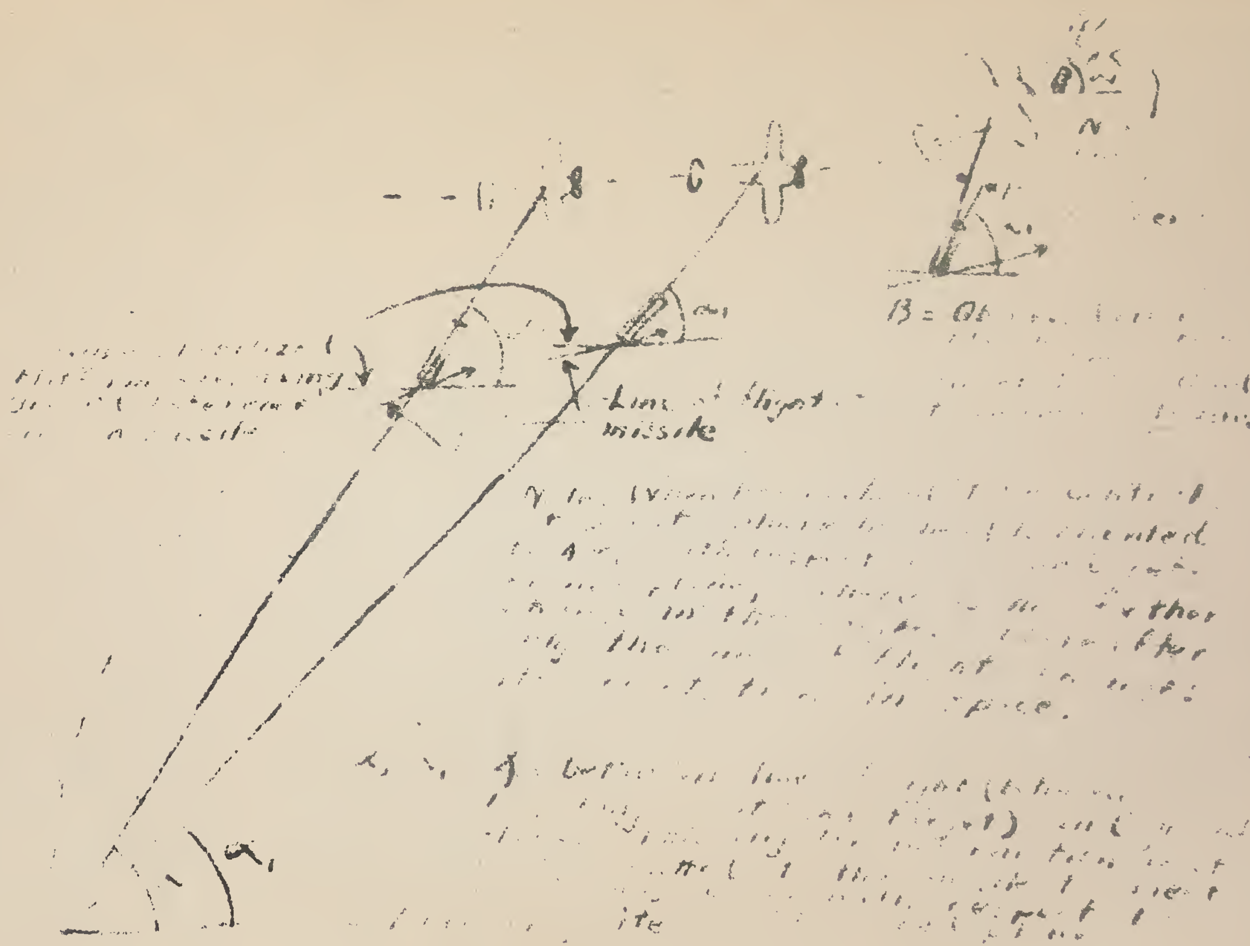


Fig 2

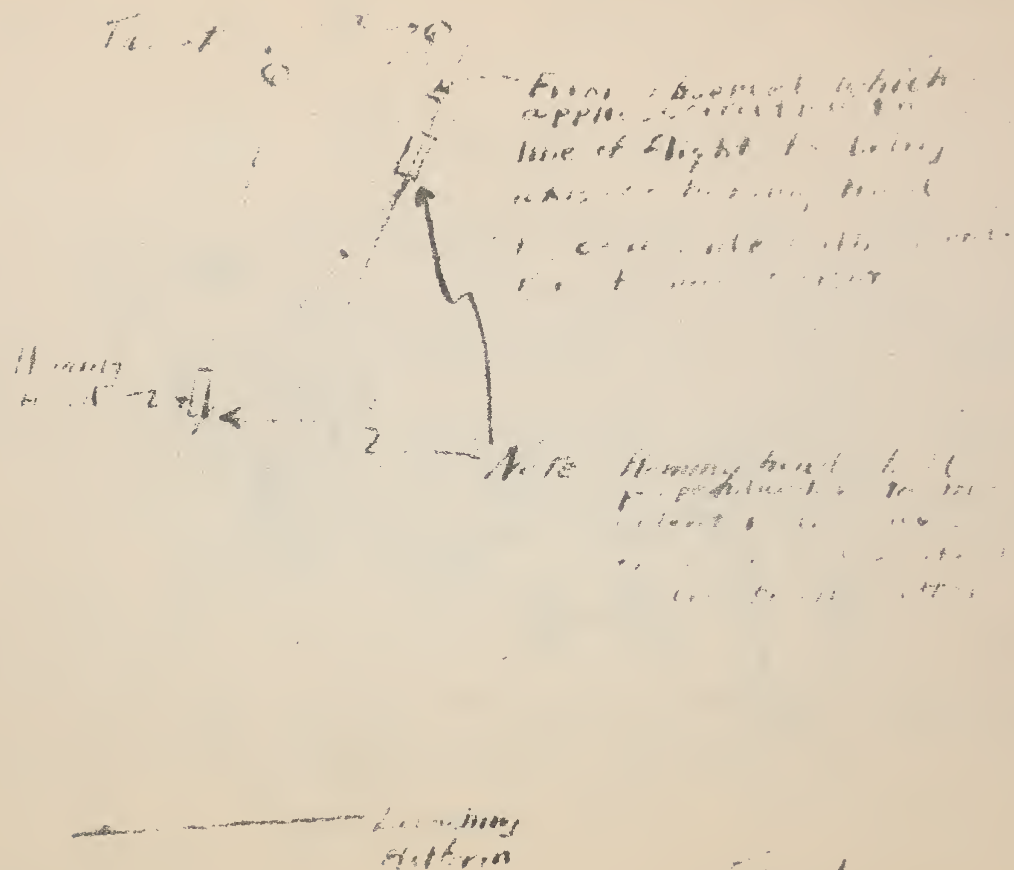


Fig 1

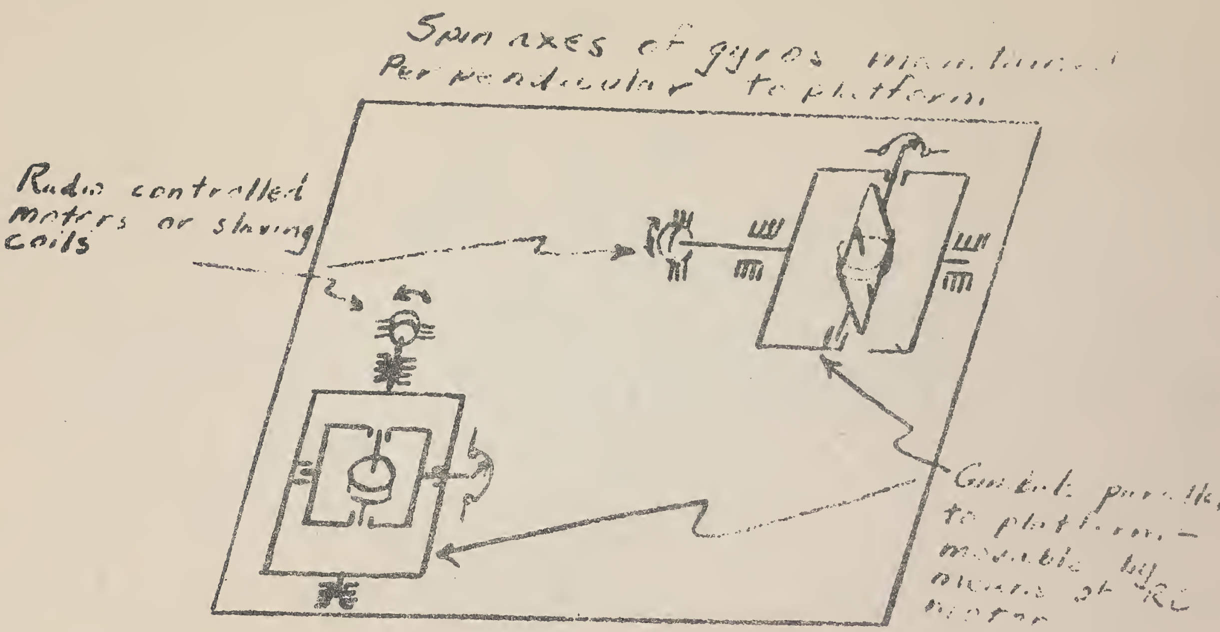

Spin axes of gyros maintained
Perpendicular to platform
Radio controlled
motors or slewing
coils
Gimbals parallel
to platform –
movable by
means of RC
motor

Fig 3

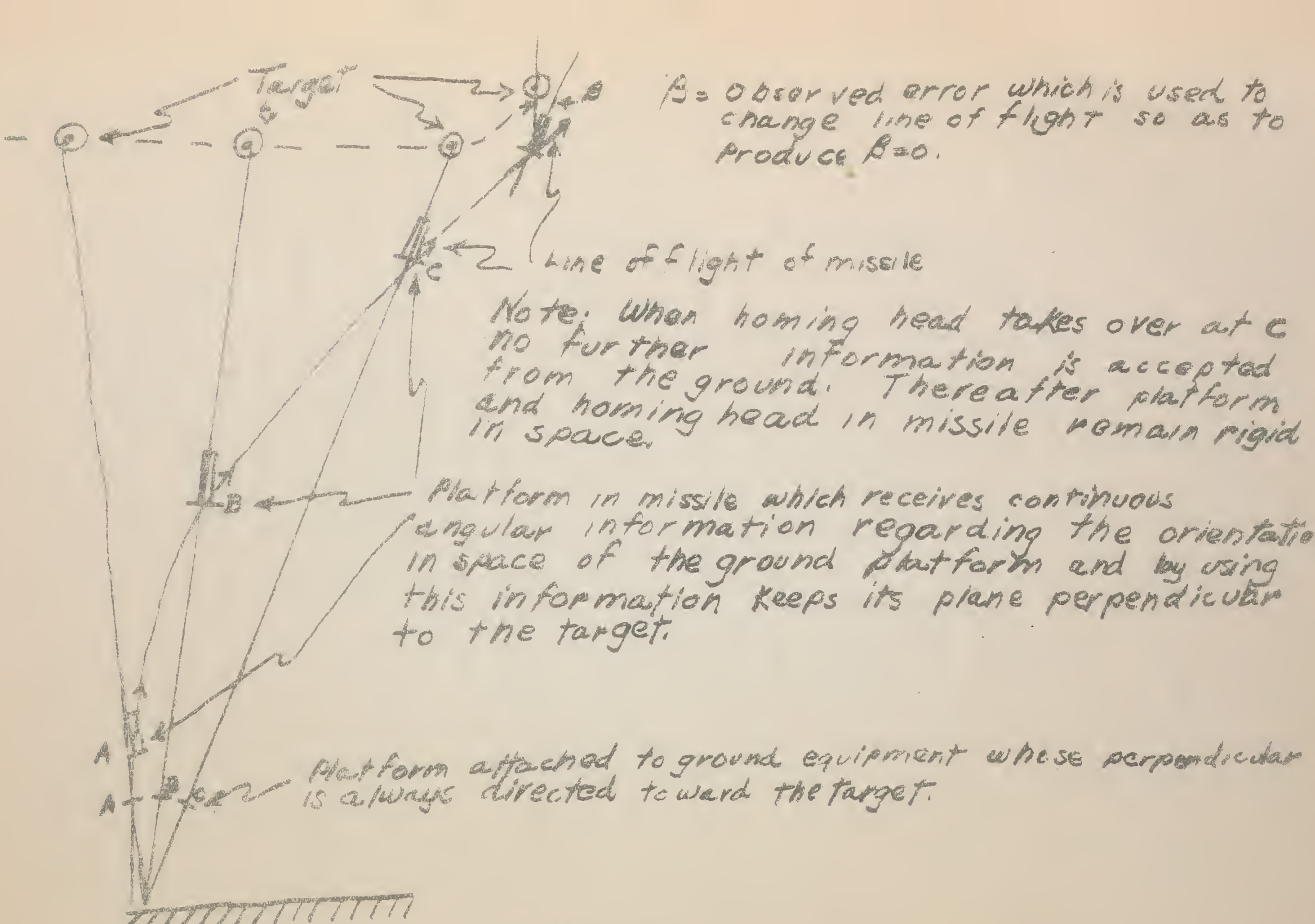


Fig 4.

2 Dimensional Presentation Krücke B (2nd method)

TARGET SEEKING EQUI[illegible] PLANE TO PLANE

The target seeking equipment for plane to plane service was worked out along the same principles as the ground to plane devices with the exception that the Krücke problem was absent. The axis of the homing head was gyro stabilized in order to provide a fixed reference line in space as described in the previous ground to plane discussion. However, in order to make the equipment less bulky and of lighter weight, the rotating parts of the scanner are used as part of the mass of the gyro and the stabilizing force is obtained through the gyro itself in place of merely using the gyro as reference with pickoffs and driving mechanism driving the device to be stabilized. The homing head, therefor, may be mounted in gimbals and is stabilized in space irrespective of the motion of the missile.

Weiss stated that for plane to plane operation they had come to the decision that a field of view of approximately 10 to 15 degrees was desirable. With this field of view they expected to obtain a range of about 2 kilometers which they felt would be satisfactory. An accuracy of 0.2 desree was expected. A previous interrogation by Dr. Zwicky has described certain details of this system, which will not be repeated here. The technique of launching in order to bring the target within the field of view of the homing device is as follows: the launchin plane is brought to within the operating of range of the homing device on a course directly toward the target. When it has been observed that the homing device has picked up the target, the missile is released. The launching of the missile on a collision course is not necessary. Attack my be made from any angle, and the homing device is designed to each a collision course in the best and quickest manner. This is done by means of the computor, which is inserted between the output of the homing device and the control surfaces. Weiss described the operation of the computor as a function B=F (e,t) where epsilon is the error observed by the homing device, or a quantity proportional to the angle off target, and t is time. He does not know the exact nature of this function, except that is must: (1) result in a stable course, (2) give the best possible pursuit course, (3) take into consideration the particular characteristics of the projectile on which it is used, and suggests that Dr. Geissler is the best source for further information.

While this homing system was originally designed with the intention to apply it to the X-4 missile, the rolling of the missile prevented its final application, as the added difficulties made necessary by the rolling motion necessitated additional complexity for proper operation.

Incorporated in the infra red homing devices under his cognizance are several types of scanning systems. The first type consisted of a rotating shutter which had the shape shown in figure 1. The shaded portion of the shutter is opaque and the remainder transparant. The shutter when XXXX rotating interrupts the infra red target picture which has been focused on a screen in front of the shutter. The interrupted infra red beam is intercepted by a photocell with the result that the output of the photocell has an approximate square wave whose duty cycle will furnish the information as to the distance of the target from the center of the screen and the phase when compared to an arbitrary reference phase on the rotation of the shutter will furnish the information as to the angle of the target. Thus the target picture focused on the screen has its position given in polar coordinates at the output of the photocell. Rho is thus the duty cycle and theta the phase difference with respect to the reference phase of the shutter.

It was felt by Dr. Weiss that better accuracy could be attained with a more complex shutter structure, which he claimed as his developement. The structure of this shutter is shown on figure 2. Here also the shaded portions are opaque and the unshaded portions transparent. As before the infra red target picture is focused on a screen in front of the shutter and the shutter when rotated interrupts the infra red beam to the photocell. At the center of the shutter the central angle of each shaded portion is identical and the spacing about the center is uniform. It will be noted from figure 2 that as we proceed from the center radially each opaque portion has a different shape and size. The smallest opaque sector is directly opposite the largest one, and the remaining ones are greater from this minimum to maximum value. When the target appears at the center of the screen, no output results. When the target image is away from the center of the screen, the output of the cell will appear as a frequency-modulated square wave. As the distance of the target image from the center increase, the frequency deviation of the FM square wave increase; furthermore, the shutter is constructed so that the frequency deviation is directly proportional to the distance of the target image from the center of the shutter. The phase of the frequency modulation will give the angle off target when referred to an arbitrary reference phase of the shutter shaft. Therefore, polar coordinate information is obtained with rho given to the frequency deviation, and XMdaX theta given by the phase of the frequency modulation. A report on an infra red system using this type of scanning has been prepared from PW interrogation and reference can be made thereto for further information.

Another type of scan investigated by dr. Weiss is shown by the shutter diagram of figure 3. The shaded portion is opaque and the unshaded portion transparent as before. When the target is focused at the center of the screen, a constant ouptut results. The target image should be very nearly the size of the transparent portion of the shutter. When the target image is away from the center of the screen, an alternating output voltage results. The amplitude of the output voltage gives the distance off target, or rho, and the phase of the alternating voltage when referred to an arbitrary reference on the shutter shaft gives the angle off target, or theta in polar coordinates.

The same result as in method 3 can be accomplished without a shutter by placing the infra red lens eccentrically with respect to the axis of the homing device and rotating it. The photocell center is then placed on the axis of the homing device and in the plane of the focused target image. The photocell should be approximately the size of the target image. The output of the photocell is then identical with method no. 3.

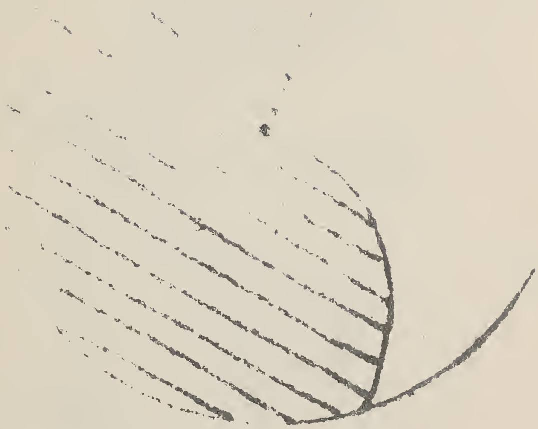
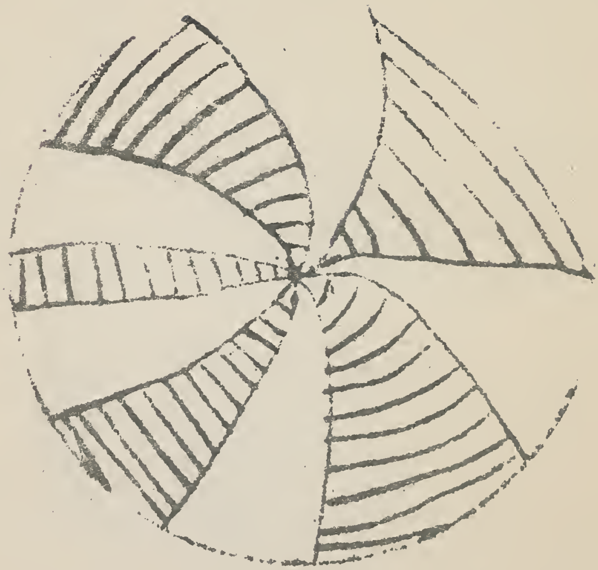


Fig 2



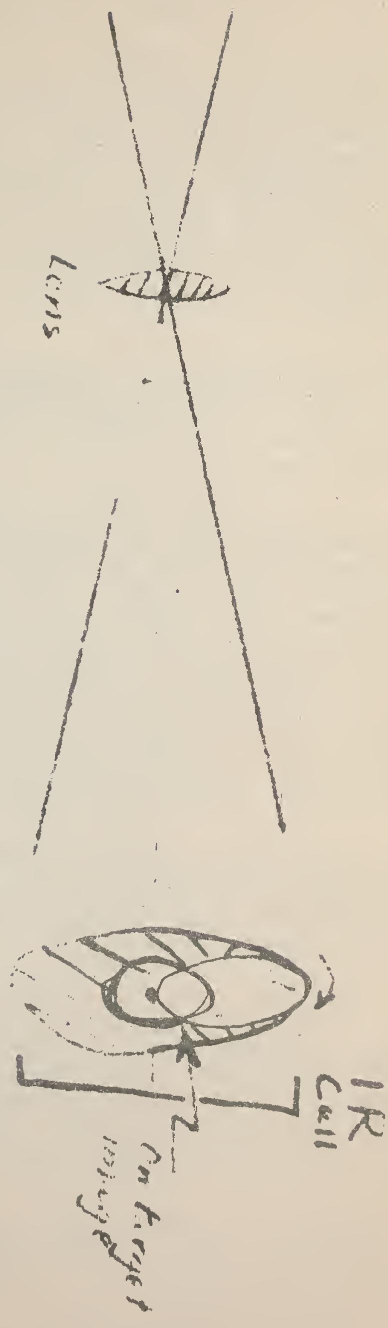


Fig 3

INTERROGATION OF DR. HELMUT WEISZ -21 May 1945 and 25 May 1945.

By- S/L Sharpe, F/Lt. Stokes, Dr. Porter at Partenkirchen.

Dr. Weisz described his work as consisting of the design and application of homing systems, principally of the infra-red type. He described three general classes of homing missiles: one ~~(x)~~in which the axis of the homing deviceis coincident with the axis of the missile, one in which the axis of the homing deviceis controlled by an air foil so that itpoints along the target to the flightpath, and third, the type known as constant bearing approach, in which the axis of the homing device is fixed in space by gyro stabilization. For a description of this last system see report of this date on Dr. Geissler.

He mentioned that he had been interested in homing devices for air to air missiles, and regarded them as the most useful application, particularly if a range of 2 km is obtained so that the missile can be fired from a safe distance. The X-4 was mentioned as a possible missile in this class.

The infra-red homing system for theWasserfall has been tested in the laboratory but no flight model has been completed. The link to the steering was worked out only theoretically. For this installation, the entire nose section was to be made of special glass(~~pxxx~~ probably iron-free flint glass) of which several samples were tested. One sample had been supplied by Prof. Kliefoth, of Breslau; infra-red properties were satisfactory, mechanical properties had not yet been tested. This nose section was to be 8 to 10 mm thick, and could be moulded, blown or centrifically cast. The max. temperatures for the nose was calculated to be about 200°C. which the glass could stand without difficulty. Presumably the lenses, if any were used would be of the same glass; in the laboratory systems mirrors were used.

The range of infra-red homingsystems, in general is one to twenty kilometers, depending on the angle included in the field of view. For Wasserfall the range was supposed to be 3 Km with a 6°field. Dr. Rosenthal was following the work on infra-red devices which was being made at Leitz.

Only two infra-red cells were available for this development, the Zeiss-Ikon from Dr. Görlich and the Elektro-Akustik from the company of that name at Namslau. A.E.G. were also working on a cell, as were many others. Prof. Wesch's cells, according to Dr. Weisz, were "still fighting for recognition". Baron Von Pfeifer who had a direct order from Flak Kommando, has developed a long range infra-red device with a small angle, and has designed a clever scanning device to be used with it.

A radio homing method for Wasserfall was being developed by Blaupunkt in Berlin. Itwas a passive short wave system, ~~xxxx~~ among otherthings designed to home on our "Meadow" system. Dr. Weisz had never seen this device but said he had heard the name "Stiel Strahlem" (Rod transmitters) used in connection with it. For the radio installation, glass, wood, or artificial resin noses were being considered.

Interrogation of Dr. Helmut Weiß, continued-----

Although no decision had been reached as to what robot type of control was to be used, and in fact none were ready for use, it seems likely that a combination of line-of-sight for the first part of the curve, and constantbearing homing would have been at least given a trial had time permitted. Dr. Weiss also mentioned the problem of getting the target into the field of the homing device initially, and its two solutions, W/T of angle data from the ground and D/F on the ground transmitter, mentioned in the report on Dr. Geissler. Difficulty was expected in radio control through the ionized gases of the beam. Dr. Weiss said that there were methods for overcoming this difficulty, but he preferred not to discuss them.

Acoustic homing methods were not favored by Dr. Weiss for obvious basic reasons, in spite of the fact that they were highly regarded in official circles.

R.W. PORTER

A-18

Garmisch-Partenkirchen.
May 19th, 1945

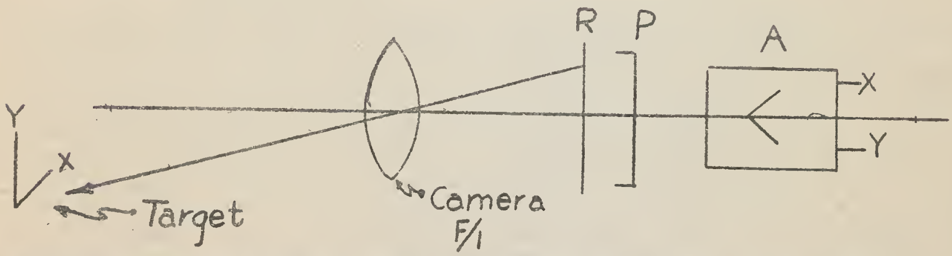
Interview with Dr. Helmut Weiss

Interrogator: Dr. F. Zwicky.

Worked "Ultrarotes Zielsuchgerat"

(Infrared Homing device) for "Wassefall" and the projectiles from plane to plane.

Principle (See Sketch)



Camera either mirror or lens optics (Flint Glass or special infrared transmitting glass from Jena). A = amplifier

R = Rasterscheibe (scanning opening covers the whole field, 25, or 50 or 100 times per second.)   Example:

Aperture of lens = 5 cm

Focal length = 5 cm

(Definition of image relatively poor)

Scanning disk = 8 mm diameter with an angular total field of of view of 6°.

P = Photocell of semi - conductfor such as PbS. Internal photo effect used and change of resistance registered.

Weiss does not know what the lowest in-frared radiation density is which can be registered.

If one restricts oneself to a field of 0.5° then an airplane can be picked up at a distance of 15 km.

2. Very approximately

Gesichtsfeldwinkel x Reichweite = konstant

(field angle x range = constant).

If a large field is demanded the photo cell has to be unnecessarily large and the current small.

A = amplifier and DC current or voltage indicators which register two coordinates of the image (object).

Essentially the above scheme was used generally in Germany. and the apparatus was relatively readily available. With mirrors, systems were tried of the Schmidt camera type and the Schwarzschild type.

3. The Real Problem was to feed the signals into the steering mechanisms of the missiles. It was not realized in Germany how many fundamental difficulties this problem involved. Each change of position of the target falsifies or influences the signals in the receiving devices. On change of the incoming infra-red beam the indicated signal values change very quickly and may raise havoc with the stability of the controls homing the missils. Here the real problem begins. Weiss was well on the way to solving the problem. Test were essentially conducted with homing missils at night. "Contrast" receivers for use in daytime were considered.

4. Chronological Remarks. Solution of the difficult problems mentioned appeared the easiest with optical methods of the type described, according to the Peenemunde group. Most attention in Germany, however, was paid to acoustical devices, which

Dr. Weiss considers as an unfortunate choice. With Electrical homing devices, relatively rapid progress was made only very recently, and Weiss group was engaged to work out the linking of the radio reception and the mechanical flight control mechanisms.

Ing. Zeike.

1. Operational data of the singly constructed parts of the driving gear for the V-2.

Oven:

Oven pressure		15.45 ata. when putting through 125.2 kg.
Thrust		25,700 kg
Ratio of Expansion		
In Laval Jet $\frac{pa}{pi}$	=	$\frac{0.85}{15.45}$ ata
Theoretical exhaust velocity when using Methanol mixture		2245 m/sec
Actual exhaust velocity		2000 m/sec
Temperature		3000°C
Narrowest diameter of the jet		400 mm.
Widest diameter of the jet	approx	700 mm.
Thrust gain at the end of the trajectory	=	4200 kg
p Injection pressure of O_2	=	2.4 at
p Injection pressure Br.	=	2.4 at
p Cooling mantle Br.	=	4 at

Pumps and Turbines:

O_2 Pump wheel diameter	=	284 mm
Necessary pre-pressure against collapsing	=	2.5 ata
Revolutions during flight	=	3800 rpm
Conveyor pressure at 3800 rpm	=	18.2 ata

Br. Pump:

Ø of wheel	approx. 326 mm
Revolutions during flight	" 3800 rpm
Conveyor pressure at 3800 rpm	" 21 atu

Turbine:

Revolutions during flight	" 3800 rpm
Fresh stream pressure	" 28 ata
Exhaust steam pressure	" 1.8 ata
Pressure in Laval exhaust steam jet	" 1,3 ata
Steam consumption	" 2.2 kg/sec
Degree of efficiency of turbine	" 30%

T-S+off Steam Installation:

Pressure medium	Compressed air
Initial pressure	approx. 200 atu
Final Pressure	" 70 atu
Low pressure	" 33 atu
Pressure in T and Z-Stoff tank	" 31 atu
Pressure in the disintegrator	" 30 atu
Amount of steam passed through	" 2.2 kg/sec.
Amount of T-stoff in the tank	" 126 litres
Amount of Z-Stoff in the tank	" 10.5 litres
T-Stoff	H_2O_2
Z-Stoff	MnO_4

Heat Exchanger

Intake temperature	approx. 183°C
Escaping temperature	" + 40°C
p Exhaust steam	" 0.3 at

O_2 Tank

Total volume	approx.	4430 litres
Amount of O_2 in tank	"	4970 kg
Pressure in tank during flight	"	2.2 ata
Temperature of O_2	"	- 183°C

For pressure in tank while in flight, see sketch No. 1.

Br. Tank

Total volume	approx.	4580 litres
Total amount of Br.	"	3965 kg

For pressure in tank during flight see sketch No. 1.

Sūpplementary Ventilation for Fuel Tank:

Pressure medium		Compressed air
High pressure	approx.	200 atu
Expansion over throttle diaphram to	"	1.4 ata

2. Operational data of the entire mech [illegible]ism

Empty weight of the apparatus	"	4000 kg
Starting weight of the apparatus	"	12800 kg
Amount of O_2 in tank	"	4970 kg
Amount of Br. in tank	"	3965 kg
Initial acceleration	"	0.9 g
Final acceleration	"	5 g
Combustion time	"	63 sec.
Thrust (without regain)	"	25700 kg
Ratio of mixture: Br : O_2	"	0.81
Passage through the speed of sound	"	in the 25th of a sec.
Acceleration in the 8 to - stage	"	1.7 g

Duration of the 8 to stage	approx	2 - 3 secs

3. Trajectory Data

Initial acceleration	"	0.9 g.
Vertical flight	"	4 sec.
Guided (?)	"	50 sec.
Final angle in approx. 54 sec.	"	49° to vertical
Altitude at end of combustion	"	22 km
Range above ground at end of combustion	"	24 km
Altitude at culmination point	"	80 km
Velocity at culmination point	"	1200 m/sec.
Speed of impact	"	900 - 1000 m/sec
Range	"	290 km.

Some of the above data taken from memory is of medium value. The tolerance of the individual values is sometimes very considerable and thus very different for the separate apparata. The tolerances were laid down on the strength of knowledge gained from accuracies and various degrees of value and efficiency. The various tolerances were obtained statistically and formed the averages given above.

Sketch 1.

Parten Kirchen 18 May 1945

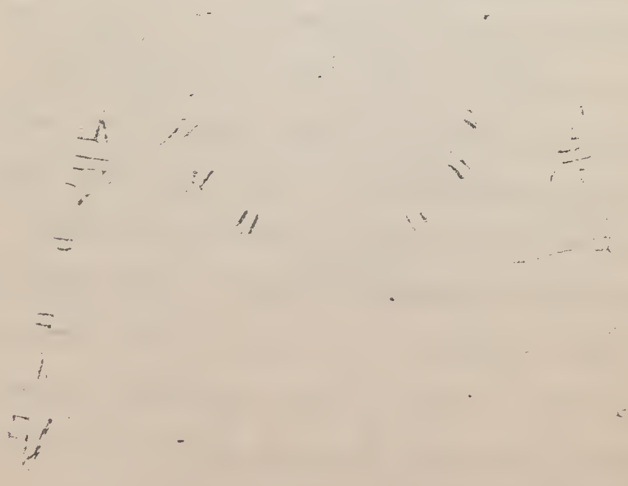
A short description of the V-2 "Power-Unit" by Ing. Zoike. (EW 21)

The construction of the power unit is divided into several main groups, the function and purpose of which is briefly described here. I wish to make it clear that this is only a short illustration of the power unit since a comprehensive description without drawings control schemes or control figures would be impossible.

A. The Rocket Oven.

The Rocket Oven is almost a sphere shaped combustion chamber for the internal combustion of the liquid fuel, annexed to this is a Laval nozzle in which the combustion pressure and gases are transformed into speed. The fuel fluid is injected by a special injection system into 18 single pots, in which the fuel is atomized. The oven has double walls between which the fuel stuff is conducted. This cools the oven and reduces the high combustion temperatures. For a quick combustion, a "shut-off-valve" is constructed in the head which also is used as an alternating valve to prevent a hydraulic thrust. (Back flow to the pump). Since the cooling of the oven is not sufficient with only the fuel flow, it has its own injection chambers in certain dangerous places out of which fuel is injected for cooling purposes over corresponding throttle diaphragms. In addition, the oven has in certain places so called expansion joints in order to prevent "tension-cracks". The injection system is empirically constructed as the result of years of experience; its record and durability were tested on a single pot and recommended. The combustible surface is placed as far as possible from the injection system by a corresponding arrangement and cooling of the individual jets endangered by the fuel. The forming of excess oxygen zones is impossible due to proper partitioning (proved by gas analysis measurements in the jet during combustion). The Laval nozzle is only about 2/3 cooled, the last 1/3 is insulated by glass wool and a sheetmetal covering

SKETCH OF THE INJECTION SYSTEM



B. The Turbo-Pump Unit.

The turbo-pump unit supplies the liquid fuel and consists of a "Drive Turbine" and a rotary pump to conduct the liquid oxygen, and a rotary pump to conduct the fuel. For reasons of weight, it is constructed of light metal. The turbine is a two stage Curtis turbine, the bearings of the turbine are ball-bearings, and the packing is Simmeringen. In order to prevent cavitation within the oxygen pump, the "liquid oxygen" must be forced into the pump with an initial pressure (2,5 ata). This initial pressure is made by the "Heat-exchange" during the flight.

C. The Heat Exchangers.

As already stated, the heat exchangers create the pressure gas for the initial pressure of the O_2 pump. For this reason, the liquid oxygen is fed from behind the main O_2 valve over a throttle diaphragm ar a check valve thru a pipe system into 3 pipe coils and are vaporized there by the exhaust steam. The gas forming oxygen is conducted thru corresponding pipes into the O_2 tank.

D. The Steam Installation.

The steam installation is used to form the fresh steam necessary to drive the turbines. The fresh steam is created thru the catalytic decomposition of 80% H_2O_2 into water vapor and oxygen. As a catalyst, a manganese tetraoxide solution is used (MnO_4). The decomposition takes place in the so called decomposer or steam mixer. In order to supply the T-Stoffe and the Z-Stoffe, compressed air is used which is released thru a pressure reducer (regulator). The compressed air is carried in a high-pressure battery. (200 atu).

The fuel tank is closed through the pneumatic controled liquid valve for the 25 and 8 to stages on the liquid side and the pneumatic controlled releaser on the gas side.

E. Fuel Tank.

The O_2 fuel tank is used for the intake of the liquid oxygen and is constructed for an excess pressure of 3 atu. The fuel intake tube runs through the middle of the tank to the pump. The gas room is inter-connected with the outside air through an ascension pipe with a double valve (releaser). The flow to the O_2 pump is effected by a spring. The upper tank is constructed with a manhole in the bottom. There is a connection for a so called fuel limiter in the electric system.

The Br. fuel tank is used for the intake of fuel and is constructed for an excess pressure of 2 atu. The flow to the fuel pump is effected through a tube 3 meters long, which runs thru the oxygen tank. To prevent freezing, the tube is insulated with glass wool.

The oxygen tank is also insulated with glass wool in order to prevent a large heat intake and consequently large vapor losses in the oxygen tank. In order to prevent a large heat intake during free flight, the Br. tank is also insulated.

F. The Auxilliary Ventilation.

The auxilliary ventilation has the purpose of blowing up the apparatus of V-2 as it returns into the atmosphere in order to have the inside pressure higher than the outside pressure so the tank will not collapse. (See V-2 power-unit data, sketch 1).

G. Armatures.

In the apparatus A-4, there are about 45 different armatures. They have the purpose of automatically connecting the separate processes by electrical impulses. Various kinds of instruments are used.

Group 1: Electro-Pneumatic Valves that receive the electrical impulses and control the compressed air and so activate the individual pneumatic valves. These are the so called auxilliary valves.

Group 2: Pneumatic valves that control the fluid or the gases. They receive their working pressure from the electro-pneumatic-auxilliary-valves.

Group 3: Servo controlled valves. These valves are used on small sections and for small current capacities. They unite Group 1 and 2 into a single valve, and are more advantageous from the point of view of weight.

Group 4: Hand operated valves: The valves are used before the take-off and consequently are generally of simple construction in the shape of usual industrial valves.

Group 5: Non-return plates: To let the fluid pass in only one direction and by flow changes will close the system.

The greatest difficulty in the development and connection of the armatures are to make them fool-proof so they will work fully automatic without failures as is not usual in the construction of armatures. For example: if the armatures of an airplane should fail it could still be held serviceable by auxiliary or emergency control, the same is true of a truck or any other gas engine. But, if only one instrument of the A-4 should fail, the result would be the loss of the entire apparatus. Since the number of armatures is very high, and even if each instrument is 99% fool-proof, the loss would still be 30%. This then is the greatest difficulty in the whole rocket technique.

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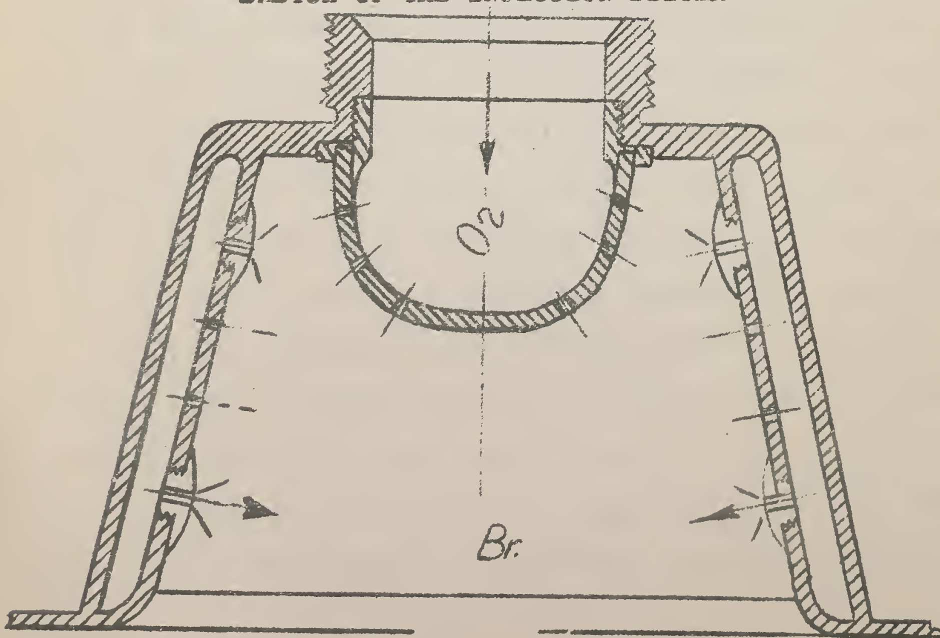

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Interrogation of Dr. Wurster, 19 May 1945.

Wettersteinstr. 8, Partenkirchen, H.M. Stokes & R.W. Porter.

1. Prior to 1940, Dr. Wurster was a test pilot for Messerschmidt. He had flown 109, 209, 309 and 409, and the 163, attaining speeds in excess of 1000 Km/Hr.

2. Since that time he had specialized in design, particularly aerodynamics, and recently had been chief design engineer for the "Enzian". He claims that he was responsible for this weapon almost single handed.

3. "Enzian" is really a rocket-propelled aircraft having a wing similar to the Me 163, and two control surfaces which act both as elevators and as ailerons. There are no horizontal tail surfaces, and no rudder, but there is a vertical tail surface. There is no dibedrol, and the plane of the wing passes through the middle of the fuselage.

4. The following data was given by Dr. Wurster as applicable to Enzian IV.

(a) Wt. at start (total) is 800 Kg.

(b) Wt. of four A.T.D. units without fittings is 144 Kg. (36 Kg. each)

(c) Wt. after 5 sec. when A.T.D. have been dropped is 1500 Kg.

(d) Main thrust is 2000 Kg. at start varying linearly down to 1000 Kg. at end of 70 sec. burning time.

(e) A.T.D. thrust is 1500 Kg. for each unit, i.e. 6000 Kg. total.

(f) Range at end of burning is 12 Km. Continues without thrust to 16 Km.

(g) Weight of fuel is 450 Kg. (When it was pointed out that this, together with the above data gave a specific fuel consumption of about 4.26 J/Kg sec., he decided that it was 550 Kg. that was the design figure, and that 450 Kg. applied only to the test missles.

(h) Propelled is Solbei and Wisol, 1.4 to 1 ratio.

(i) A.T.D. uits use Einbeiz Pulver. Dr. Wuster doesn't know the composition.

(j) Wt. of warhead is 500 Kg.

(k) Launching is at any desired angle.

(l) Speed after 5 sec. is 150 M/Sec.
Speed maximum is 300 M/Sec.

(p) Maximum allowable wing loading is 7.7 g.

The control is strictly line of sight, the problem being considerably simplified by the angle launching. Firing is done as far as possible in advance of the approach of the target overhead so as to reduce the required curvature of the flight path. This gives use generally to an angle attack from head on.

Below 6000 meters, the target and the missile can be tracked optically by a Flak gerat 44 range-finder. In bad weather, or for higher altitudes, the Mannheim Funkmessgerate are used. The angle between the target and the missile is measured, and presented on a C.R. tube to the operator. The missile is then controlled by a Kaeblgerat or by the newer Brigg-Kozze (not yet in production).

The Brigg-Kozze uses a 50 cm transmitter, code name "Kran", and receiver, code name"Brigg", designed by Telefunken, Group E.Z. headed by Dipl. Ing. Schwarz, and including Dr. Ing. Schurmacher. This system, according to Dr. Wurster used only one carrier, modulated with four tones of different frequencies, one each for up, down, right, and left. Twelve different wavelengths could be selected by means of a switch. The chief advantage of the Brigg and Kozze was lack of fading difficulties and greater difficulty of jamming. The only anti-jamming feature known to Dr. Wurster is the directional receiving antenna on the missile which has a beam width of about 45°.

Twelve of these weapons were made at Messerschmidt's Augsberg Plant and later on at Sonthofen bei Immenstadt (fuselâges). All were flight tested at Peenemunde, at the Startstelle Stand. The propulsion units for these flight-test models were assembled by Walther at Lanbau. Dr. Conrad in Berlin is considered better a source of propulsion units by Dr. Wurster, however. Serious production was to have been assigned to a firm in Eberswalde. Dr. Wurster couldn't remember the name, but had it in his papers which had been taken to Ober Amergan.

An Enzian V was planned which would have attained supersonic velocity, but none have been built. Acoustic, infra-red, and radio homing methods were also being considered. Acoustic was not good for this application according to Dr. Wurster because it did not give sufficient range. Infra-red and electrical means were expected to be ready for tests this summer.

Conclusion.

Dr. Wurster is obviously well informed on the design of "Enzian", particularly the aerodynamic and flight characteristics, and should be able to give valuable information on other Messerschmidt products. It is recommended that he be retained with the other personnel and material from Messerschmidt pending a general investigation of that institution and that he be interrogated by any guided-missile team studying "Enzian".

R.W. Porter

Location: Camp Haiming, St. Leonhard, in Inn Valley west of Innsbruch
Subject: "Natter" Interceptor Project
Investigated by: Navtecmiseu Team, Lt. C.L. Poor, USNR, Lt. A. Hyatt, USMC, and Dr. C.B. Millikan.

Reported by Clark B. Millikan
8 June 1945

INTRODUCTION

Prior to the investigation of this target a number of assessment reports were made available to the team, but there was no indication that any careful investigation had been made. The assessments differed widely in their estimates of the importance of the development. It was accordingly decided to make as careful an investigation as possible.

HISTORY OF PROJECT AND ITS INTENDED TACTICAL USE

The project was initiated Aug 1, 1944 by the Bachem-Werke, Waldsee under the sponsorship of Oberst Knemayer, Chief of Development, RLM. Its purpose was to act as an interceptor against the Allied high altitude bombers. At the end of the war 150 planes were on order by the SS and 50 by the Luftwaffe. The designers were Herr Bachem, Formerly Technical Director of Fieseler, and Herr Bethbeder, a Dutchman who had studied at Stuttgart, was brought to Germany in 1940, and worked at Dornier before joining Bachem. Late in April the factory was disbursed, Bachem in Waldsee, and Bethbeder with group of Technicians taking four planes to St. Leonhard where they were when the US Army arrived. Beofre the dispersal Bachem had some 600 workers of whom about 300 were engaged on Natter, including approximately 60 engineers. It was planned that production on a considerable scale would be carried out in a large number of small factories and shops scattered over Germany. The design had been very consistently worked out so that only unskilled workers and the most common and readily available materials would be required. Lightness and complexity were everywhere sacrificed in the interest of cheapness, simplicity, and absence of elaborate jigging and construction tools. The plane was to be used as a "one-shot" device being destroyed after its initial flight and contact with the enemy. The basic materials used were the commonest grades of wood and the cheapest quality steel.

The German government had planned to sell the Natter plans and all construction details to the Japanese. The engineers interrogated were unable to tell whether or not this plan had been executed, and it is believed that they were actually ignorant in this connection. The plane should be tactically very useful to the Japs and the type of construction should be highly suited to manufacture in Japan. The possibility that Japan may be able to undertake the project is, accordingly, one of its most significant features.

PERSONNEL INTERROGATED AND THEIR DISPOSITION

The following members of the Natter group had been held for some M weeks at Camp Haiming. After careful interrogation of the key persons, the entire group was returned to the town of Jerzens near Wenns. This was approved by the Military government officer at the camp. All of the men were instructed to report daily to the Burgomeister of Jerzens and to be available for further interrogation should this be desired. The house number where each man lives is indicated opposite his name:

H. Bethbeder	20	R. Granzow	32
G. Schaller	30	K. Schaller	30
H. Zubert	142	H. Jonas	142

Bethbeder, who speaks and understands English fairly well, was interrogated for several hours and furnished most of the information on the project. He was very cooperative and apparently with held no information on matters of interest. He impressed the team as an extremely ingenious and capable engineer. The project has so many unorthodox and unusual features that it is apt tp appear unrealistic and "crackpot". Bethbeder was able, however, to demonstrate that each of the unorthodox elements had been carefully worked out and engineered in accordance with a consistent and very reasonable conception of the overall problem.

Zubert was the test pilot fo the project and furnished considerable information on the flying characteristics of the glider version which he XXX had flown.

Granzow was Walter's pepresentative on the project and was responsible for the functioning of the main rocket motor. He contributed relatively little to the teams knowledge.

G. Schaller was sent by RLM as a liaison man and inspector for development and production. It was stated that he might have been a Nazi party member, but that he had not been active in the party. His interrogation contributed little.

K. Schaller and Jonas were talked to only very briefly since they apparently were workers who knew very little about the project.

Bachem who was co-designer with Bethbeder, remained at Waldsee when Bethbeder's group evacuated to the Inn Valley. He planned to bury a com.-plete set of Natter drawings and technical data in the Waldsee area. It was agreed that he nd Bethbeder would later apptempt to establish contact by leaving messages at the latter's ski hut "Einen Eckalpe" at Oberstaufen, 15 Km from Isny. This town is near Kempten south of Augsburg. The rendezvous has not yet been effected but Bethbeder believes that Bachem is probably in the neighborhood of Isny.

CHARACTERISTICS OF THE AIRPLANE AND LAUNCHER

The Natter is essentially a very inexpensive single seat, rocket powered interceptor which is launched vertically from a short launcher, controlled by an auto-pilot to a position predetermined by a standard anti-aircraft flak computer as being in he neighbo hood of an enemy bomber, and guided by the pilot to the target at very high speed. At a distance of a few hundred hards 24 73 mm. rockets are fired in a burst and Natter fives away. When clear of the enemy the speed is reduced to 200-300 rm/hr, the nose and then the remainder of the plane is jettisoned and the pilot parachutes to the ground.

The basic numbrical characteristics are as follows:

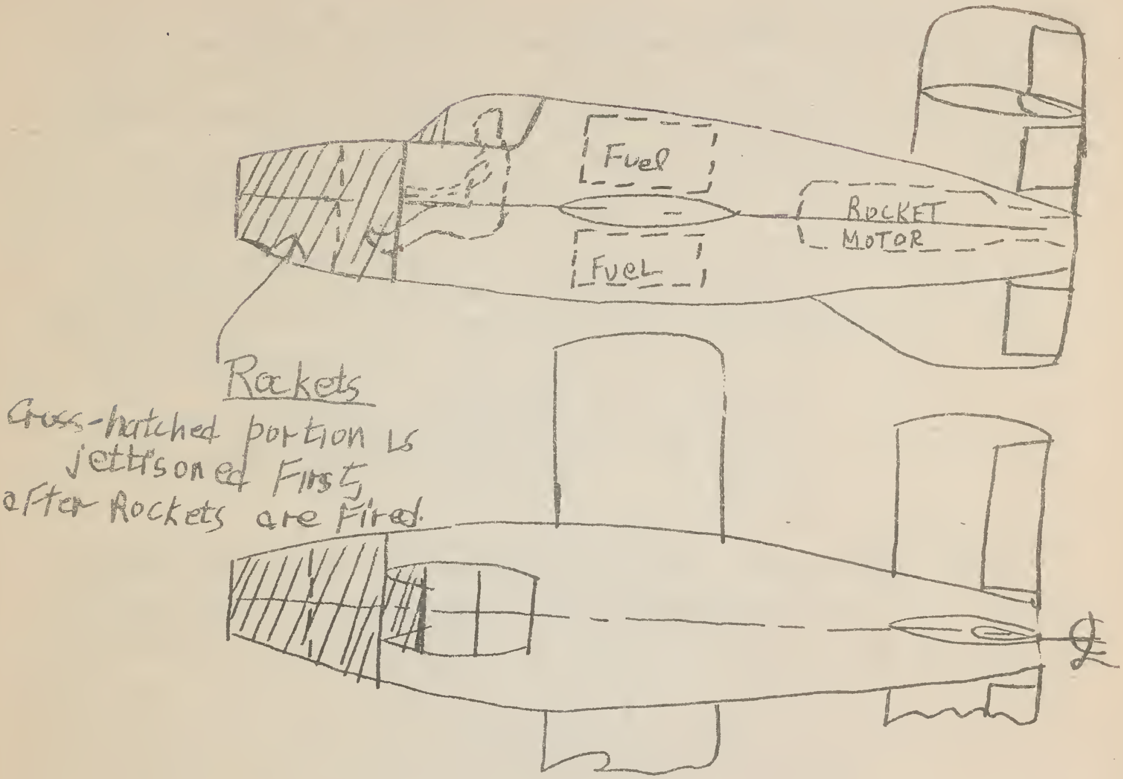
Initial weight with 4 boost rockets -- 2200 kg.
Gross weight including fuel but without boost rockets -- 1700 kg.
Fuel weight -- 650 kg
Wing area -- 3.6 m^2
Wing span -- 3.6
Horiz. tail area=2.5 m^2
Horiz tail span= 1.0 m.

Wing and horiz tail: rectangualr plan form, no dihedral, no sweepback, constant profile 12% thickness at 50% chord) symmetrical section. Vertical surface approx 2/3 above fuselage and 1/3 below. Tail setting - 1^{o} to wing. No ailerons, roll control by differential operation of elevators. Overall length - 6 m. c_{d_p} (at M=0.4)=0.08 from wind tunnel test. Launcher is circular tube projecting verically 9 m. from the ground. Boost: 4 Schmidding rockets each having 12,000 kg. sec. impulse with a nominal burnign time of 10 secs.
Main Power Plant: Walter 509 rocket motor burning C and T stoffs. Max thrust=1700 kg. Regulation possible down to 150 kg. Fuel Consumption= 5.5 gm. per kg sec at sea level full thrust. Fuel consumption=10 gm. per kg. sec at Sea level at 300 kg. Design max. level speed=800 km/hr at S.L. Stressed for 6 g acceleration at 1100 km/hr at 3 km. altitude with a factor of safety of 1.5 based on ultimate strength. Materials: Low grade wood and steel throughout except for motor, fuel tanks and piping, and main spars. Construction: Extremely simple and crude. Wood parts universally joined with glue and nails. Fittings heavy and simple. The entire design has been systematically and carefully worked [illegible]
[illegible]
out for rapid and cheap construction by inexperienced workers in small, poorly equipped shops. Weight and refinement of finish were consciously sacrificed for this purpose. Bethbeder gave the following figures for man-hous required to construct the machine in small scale production

Airframe -- 250 hours
Motor --400 manhours
Rockets, instruments, etc, 350 manhours
Total aircraft 1000 man hours ---

Armament: 24 73 mm rockets each weighing 2.6 kg and containing 400 gm of powder in the warhead.

The sketches below indicate very roughly the general arrangement:



METHOD OF OPERATION

The plane is attached to the launching tube on which it can slide vertically and around which it can rotate. A standard anti-aircraft director is placed alongside and the orientation of the plane is set, as is the elevator deflection required at the end of the verical flight so that a straight flight path will reach the predicted location of the enemy bomber. The motor and launching rockets are fired and the plane ascends vertically some 150 meters when the auto-pilot deflects the elevators and holds the plane on the predetermined straight, climbing flight path. At this time the boost rockets are dropped. When the pilot sights the enemy he takes over and when on the target and in range fires 24 rockets. He then dives away and when clear slows to about 250 km/hr, and release the nose section which is sucked forward and clear by the pressure distribution over it. The pilot then releases a parachute from the rear of the fuselage. The latter decelerates very rapidly ejectly the pilot who parachutes to the ground.

TESTS

Wind tunnel tests on models were made in Sep 1944 at DVL at 500 km/hr, and in the high speed tunnel at Braunschweig in March 1945 at speeds close to M=1. No bad effects of compressibility on stability or control were observed.

Approximately a dozen unmanned launching tests were made in every one of which the plane ascended vertically to 100 or 150 meters height where the speed was sufficient for the aerodynamic controls to become effective. The auto-pilot had nto been perfected in time for a satisfactory test with it to be mad.e. One plane without motor but with equivalent balast was towed to altitude and release as a glider. The test pilot reported the flying characteristics, up to the highest speed reached (700 km/hr), as superior to any pursuit he had flown (including all standard German fighters). One manned luanching was attempted in which it is believed the pilot struck his head and was knocked out at the start. In any event at the end of the usual vertical flight of some 150 m. the plane went on its back and dived to the ground, the pilot being killed. The end of the war stopped further experimenting.

RECOMMENDATIONS

The project appears to be interesting enough to warrant careful study of the two airplanes which the AAF apparently has, as well as to justify search for and study of the data which Bachem had at the end of the war.

Ötzal Wind Tunnel----Reported By: C.L. Poor, 3d, Lt, USNR

Investigated by: Dr. Clark B. Millikan, Tech, USN
C.L. Poor, 3d, Lt, USNR
A. Hyatt, 1st Lt, USMCR

Date of Investigation: 6 June 1945

Location of Target: Inn Valley, route 31, approx 35 Km west of Innsbruck, near Lager, Haiming.

A large high speed wind tunnel was reported to be under construction in the Inn valley, near the Ötzal. The tunnel was investigated by a Nav Tec Mis Eu Team on 6 June 1945. This report presents the findings of the team.

Description of Wind Tunnel

The wind tunnel as planned is of Steel Construction, closed throat, and capable of attaining a Mach number of one at full power, clear tunnel. The principal dimensions are:

Test Section Diameter	8 meters
Test Section Length	14 meters
Maximum Diameter	24 meters
Overall Length	174 meters
Contraction Ratio	9 meters

The power for the tunnel was to have been obtained from two 50,000 rsepower Pelton wheels, each directly connected to one of two 15 meter ameter contra-rotating propellers. At full power, the propellers were turn at about 220 rpm. In order to obtain the necessary hydraulic power, tunnel has been drilled through a mountain , the south of the site ving a 500 m. fall from the Staumaurer dam of the Westtiroler Kraftwerker, the Stuibenbach river. The dam has not yet been constructed, although ll preparations for beginning construction have been made.

Tunnel Design

The design of the wind tunnel is conventional except for the use of rect Pelton wheel drive for the contra-rotating propellers, and for the rangement of the air exchanger for cooling the tunnel and removing exhaust ses during engine tests. The air exchanger consists of an annular opening tween the large section and the contraction, together with an intake rangement in a 15 m. constant diameter section directly following the cond corner. The air exchanger was designed to handle the exhaust gases om a 10,000 horsepower plant at a fuel rate of 0.5 Kilo/hp.hr.

The tunnel is unusually long, 174 meters, and has an area ratio between e test section and the first corner of 1 to 4. The distance between the urth corner and the beginning of the contraction is approximately 28 ers, and the large section continues back through the low speed corners about one third of the distance between the third and second corner a constant diameter of 24 meters. This arrangement is apparently ded to give a tunnel of high energy ratio and uniform flow without deration of the cost of the material required for the structure.

Immediately upstream of the first propeller, the tunnel diameter decreases abruptly from 16 meters to 15 meters, apparently to speed up the slow moving air near the wall and secure a more uniform velocity profile at the propeller. There is no expansion through the corners.

Working Section

In order to facilitate changing model set-ups, and to provide for tests on complete airplane models, semi-span models, and full scale power plants, it was planned to provide three working sections, each complete with balance, mounted on wheels, to be rolled into place upon rails. To permit airtight attachment of the test sections, necessary because of the subatmospheric test section, the contraction and the first diffuser are arranged to slide on rails for a short distance along the axis of the tunnel. The contraction cone is detached from the large section because of the air exchanger outlet, and the diffuser is arranged with a sliding joint in a short constant-diameter section immediately upstream of the first corner.

Balances

The balance design is based on the use of oil pads for force and moment resolution, and hydraulic cylinders with rotating pistons for weighing. The balances were to be remote indicating, to avoid the necessity of having observers working under the low pressures existing in the test section at high velocities. No complete particulars of the balance design are available at the site, although simple schematic drawings were found. The balances were designed by Dr. Bauer, of LFM, and the first one (6 component, general purpose) is being constructed by Firma Schenk, of Darmstadt.

Personnel interviewed, and Disposition of Target.

The personnel interrogated included Dr. F. Schwaiger, of LFM, in charge of the technical phases of the construction, and C. Schindler, administrative director and expediter, sent from the RLM during the later phases of the construction in an effort to speed up completion of the tunnel. These persons are at their homes in the neighborhood, and may be found through the Military Government at Lager Haiming, or at the wind tunnel offices. Lager Haiming is a camp built originally as a labor camp for the construction of the wind tunnel and the West Tyrol power project, and is now in use as a displaced persons camp, in addition to containing a few P.W.'s.

The personnel were extremely cooperative, and showed complete sets of construction drawings, and reports describing the project and the intended construction of the laboratory of the LFM at Ottobrun, near Munich. Dr Schwaiger discussed the details of the tunnel design and, together with two of the contractors' representatives, provided information on the status of the construction contracts. This information presented in appendix 1.

The office building was found to be adequately guarded, and the occupying troops were instructed to maintain the guard and to permit no plans or documents to be removed. They were further instructed to protect [illegible] materials and [illegible] at the site, pending a decision as to the [illegible] wind tunnel project.

History of Ötztal Project.

The Ötztal project was set up as an "Aussenstelle" of the LFM, Munich. It has been planned that the LFM shoudl be a centre of aeronautical research for Southern Germany, under the sponsorship of Dr. Bauemker,..

When completed, the LFM was to have, in addition to the XXXXX Ötztal tunnel and a possible duplicate tunnel at the same site intended for engine tests only, a 2.7 meter, closed throat high speed tunnel at Ottobrun. At Ottobrun, where the central LFM offices were to have been located, were also to have been two supersonic wind tunnels, one continuous operation Guidonia type with a test section 40 by 40 cm, and the other a 25 by 25 cm intermittent tunnel. In addition to the tunnels, the project included two engine test laboratories, one for turbojets with six test stands, including equipment for simulating altitude conditions, and two conventional test XXX stands with vertical intake and exhaust to the atmosphere. The second engine laboratory was to habe been built for rocket testing, and would have provided six test stands.

The high speed tunnels of Ottobrun (2.7 m.) and Ötztal (8m) were designed by Dr. H. Peters, of LFM, formerly of M.I.T.

The construction of the Ötztal tunnel was begun in late 1942 or early 1943. At present, approximately 19 million of an estimated 26 million marks has been spent on the wind tunnel. 25 to 30 million marks XXX of an estimated 40 million has been spent on the power project.

According to Dr. Schwaiger, the progress the construction of the tunnel was slow, principally because of labor difficulties and the difficulties of transportation. All the steel work was fabricated in plants at a considerable distance from the site, and only a negligible amount of local labor could be obtained. During the last few months of the war when the possibility of loss by bombing of the only two operating high speed subsonic tunnels in Germany (Berlin and Braunschweig) became apparent, great efforts were made to rush the project to completion. Little progress has been made since February, principally because of the disruption of the German railway system. The work is well along toward completion, and could, in normal times, be completed inabout six months.

Conclusions and Recommendations

The Ötztal tunnel, if completed, would be the largest XXX high speed tunnel in the world, as far as is known to the team. The tunnel would have the ability to perform tests of complete models of high speed aircraft of greater accuracy than the tunnels available at present in the United States. XXXXXXXXXXXXXXXX It would also be uniquely suited for tests of turbojet engines and other jet propulsion arrangements and for performing high speed, high Reynolds No. tests of wing profiles, for the developement of high speed subsonic aircraft. Because of the multipel working section arrangement, a very large volume of work coudl be performed.

It is not considered practical to remove the tunnel to the United tates, since the operation of the tunnel is dependant upon the availability, of large amounts of water power, and the value of the tunnel proper is not enough enough to justify the cost of disassembly, shipment, and re-erection. If, however, it is considered desirable to operate the tunnel in situ, the tunnel could be placed in operation in six months to one year. If it is not considered desirable to operate the tunnel for the use of the United States, it is recommended that the tunnel be destroyed.

Appendix 1 STATUS OF ÖTZTAL TUNNEL CONTRACTS

I — Tunnel Structure

a. Foundation completed.

b. Steel work

The tunnel was to be built under several contracts, as listed below:

(1) Maschinenbau A.G. Augsburg-Nurenberg (MAN) (Plant where parts are being constructed is at Mainz) Contract includes:

Part	Status
Contraction	95% installed
Test Section Carriage	60% complete at factory 40% under construction at factory
Test Section	Under construction at factory, 50% complete
1st Corner	Vanes have been shipped, have not arrived. Shell under construction at factory.
2nd corner	Same as 1st corner.
1st Diffuser	50% installed. Balance at site and in transit.

- -

(2) Firma Dingler, Zweibröcken.

Part	Status
Motor Section	Installed
Air Exchanger Section	Supporting rings installed, rest under construction at factory.
2nd diffuser	Construction begun at factory
3rd corner	20% installed
4th corner	60% installed
Constant diameter section	Supporting rings installed or at site. Plates being fabricated.

- -

(3) Firma Kunze, Heidenheim

Subcontracter to Dingler, building duct work and intake for air exchanger, Work is partially completed at factory.

II POWER PLANT

a. Pelton Wheel Turbines.

These are being built by I.M. Voith Turbinenbaufabrik at St. Pölten.

One wheel is complete at site, the other completed at factory, probably not shipped. The housing for one wheel is complete at site. The toher housing has not yet been installed.

b. Propellers. Believed to be under construction by Veith. Status uncertain.

c. Shafts, bearings, and control gear. Under construction at factories. Exact location of parts uncertain.

d. Dam, tunnels, and conduits.

Dam and main inlet tunnel by Siemens Bauunion. Tunnel completed, dam construction started. Steel liner for lower part of tunnel not at site. The conduit for high pressure water distribution is being built by MAN and is being fabricated at XXXXXXXXXXXX the factory. Few parts are at the site. The status of the run-off tunnel was not exactly determined. It is believed to be 90% completed.

III -- Building

Arbeitsgemeinschaft Innerebner Mayer

Approximately 60% complete. Foundations are complete, and walls are partially built.

Scheme of Jet Motors

and the work of the group "Elektromechanische Werke at Peenemunde.

1. Jet motors using chemical energy for their activation may be classed as follows.

a. Jet motors activated by self-contained chemical propellants

1) Solid multibase propellants

2) Solid liquid propellants.

3) Liquid-liquid propellants

Propellants of the type 3) may be either multipropellants or Monopropellants.

b. The Peenemunde group (Elektromechanische Werke) has not worked on, and has very little knowledge of, motors using the propellant combinations a), b) and c_b1, the group having worked essentially only on multipropellants either of the spontaneously ignitable type (Hypergols) or of the not spontaneously ignitable type. An example of hypergol propellants is mixed acid plus optoline, which was used for the "Wasserfall" rocket.

An example of not spontaneously ignitible propellants is

Ethanol plus liquid oxygen (plus water)

which combination was used in the V_2

c. The [illegible] group used hydrogen peroxide (H_2O_2) essentially as a monopropellant (with sodium permanganate ($NaMnO_4$) as a catalyzer and water as a coolant) in the steam generator which drives the turbine pump combination for the propellant feed system of the V_2. (The hydrogen peroxide motors were particularly developed by Walter in Kiel.).

d. The main contribution of the Peenemunde group is the integration of relatively well known facts on liquid jet propellants, electrical and mechanical control mechanisms, ballistic technology and chemical design and construction into a successful large rocket, the V_2. Attention should be drawn to the fanatical enthusiasm, persistence and endurance with which the whole group worked on the very numerous problems which had to be solved to make the V_2 a practical success. A secondary contribution of the Peenemunde group was a preliminary development work on the "Wasserfall", a high speed jet propelled, partly radio guided, and ultimately self-homing missile which is of considerable interest.

3. <u>Jet motors with free air intake.</u> (Aerial duct motors). Motors of this type are:

a) The aeroduct (alias ramjet, athodyd, aerothermodynamic duct).

b) The aeroresonator (buzz bomb motor type)

c) The aeropulse

d) The aeroturbojets.

The Peenemunde group (Elektromechanische Werke) did not in any way contribute to the development of motors of the class B.). The general knowledge of the group on aerial duct motors seems negligible.

3. Underwater Jet Motors.

No development on motors of this type was done by the Peenemunde group. In fact the group in Garmisch Partenkirchen seems to have no knowledge of any kind on underwater jet motors.

4. Instrumentation, Thermochemistry etc.

No radically new results in these fields seem to have been achieved by the Peenemunde group which was interrogated at Garmisch Partenkirchen.

Examination of Equipment in Train at Pieting Station

When the Radio Equipment in the five cars of this train is finally examined it will be desirable to have present representatives from the Electro Mechanische-Werke to assist in recognising the various pieces of equipment.

The men concerned with the various divisions of Radio Equipment are given below and these would be useful for the above purpose.

a Apparatus belonging to A4

1. Dr Steinhoff as head of Electrical Section has the best general knowledge of the work in progress.

2. Karl Sendler. Carried out much of the liason with manufacturers and knows the ground equipment, most of which was built awa y from Peenemünde, very well.

3. Dr Friedrich Kirschstein was in charge of section dealing with Electrical Measurements, Integrating Accelerometers, Telometering.

4. Joachim Muhbner. Has full knowledge of Verdoppler equipment.

5. Helmut Hölzer. Has full knowledge of Leitstrahl equipment.

6. Albert Schuler. Has good knowledge of electrical measuring instruments.

b Wasserfall

7. Theodor Netzer. Has good general knowledge of Wasserfall e uipment.

8. Dr. Helmut Weiss. Has good knowledge on homing devices. He is head of the section dealing with these devices.

B.H. Sharpe

[illegible] 314 - [illegible] 5

[illegible]ber 1[illegible]

[illegible]ter [illegible]

(1) Through change to a [illegible] value [illegible] to [illegible] thanol-water mixture.

"illing [illegible] thanol-[illegible] thanol water mixture.

(2) [illegible] reducing valve setting.

The magnitude of the result [illegible]

13 kms. through changes from [illegible]thanol water mixture [illegible] [illegible]ethanol-[illegible] water mixture.

22 kms. by increasing by [illegible] setting [illegible] reducing valve.

35 kms. from the combination of the two.

295 kms. + 22 = 317 kms.
317 + 13 = 330 kms. (205 miles

[illegible]uivalent of the above in miles

183 miles + 13.65 = 196.6 miles
196.6 " + 8.05 = 204.65 "
[illegible]thanol

June 1[illegible]th, 1945.

314 - [illegible] 2 [illegible]

[illegible] the [illegible]
[illegible] units.

[illegible] August, 1944.

[illegible]le

[illegible] for [illegible] control [illegible]

[illegible] the curvature of the earth, 225.0 km.

( ) B5 setting on line of sight
3.5 km. back from the firing point II = 3.5 km.
1 km. to the left [illegible] to line of sight III = 1 km.
[illegible]ent to [illegible] - 2.1 km.

222.9 km.

(4) [illegible]ovement in [illegible] weight according to table [illegible]2

[illegible]ty weight [illegible]		2,873 kg.
[illegible]		1,000 kg.
[illegible] load		-
[illegible]		5 kg.
[illegible]teries		45 kg.
[illegible]		60 kg.
[illegible]	4,930	
[illegible] t	60	
[illegible]		4,990 kg.
[illegible] tot[illegible] table [illegible]1		3,797 kg.
[illegible] weight		12,860 kg.
[illegible] to [illegible]		12,8[illegible]0 kg.
[illegible] is [illegible] by [illegible] kg.		3[illegible] kg.

[illegible]correction according to table [illegible]2
[illegible] = 0.9 km. per 1[illegible]0 kg. [illegible] for 30 kg. - 0.3 km.

June 1[illegible]th, 1945. 222.6 km.

504A

PERTING:

Trucks of the EW-special train from Hohenpeissenberg.
Victoria (Directing Beam) arrangement complete for V-2
Victoria examination arrangement (screen)
arrangement for the total examination of Victoria.
3 model -transmittors E.
2 Victoria- examination disks
1 side integration arrangement with a measuring head
1 stabipla (stabilization platform for gyroscope outfit)
10 Treibunnen (gyroscope outfits)
3 models of the rocket-course
1 eiserne (iron virgin) Yungfrau (part of the model of the rocket course)
1 Illing, arrangements for total examination and the examination of regulation for the Mischgerät
5 Mischgeräte
2 Häusermann pendulums, different measuring instruments, examination arrangement for Mischgeräte W, motors for electrical rudder-machine and necessary examination outfit.
Sclwingtish (for examination of gyroscopic outfit)
Gummuband (special regualtion arrangement)(for Wasserfall)
Chests NO 2241/46, 48/41/ 185/187 / with a model of the rocket-course and measuring instruments.

In the Truck Nord Bdge NO 10450
1 electric transformer 20X25X25 cm (for radio control)
Kleinbahn (above mentioned)(little model of the course)
chests of the following NO 2242/ 7,14,16,26 with four tubes for electronic ray oscillators measuring instruments, measuring oscillators from 10-100 Mcls and a bridge for measuring of capacities.
40 receivers of commands
30 Verdoppler (doublers)
5 electronic ray-- oscillators
3 galvanometer oscillagraphs
measuring oscillators, examination oscillators, frequency generators bridges for measuring of frequencies and inductiveties.
measuring instruments with different ranges tubes various electrical material several equipments for V O measuring (Lalerno)
2 transmitters of commands II examination arrangements for BS (Brenschloss examination field equipments for the input and output part of the V O measuring transmitter.
1 Z (additional) equipment of the BS arrangement
2 phase-changers for LS arrangement

CAR [illegible] 21-157

1[illegible] 1945

	ITEM	NO.
1	Box with approx. 1000 receiving tubes	[illegible]0 cu. ft.
2	Development radio units 5 panels high & 2 wide	[illegible]5 cu. ft. (Photog)
2	Relay rock radio units 6 panels high F 2283/64	12 cu. ft. each
1	Box misc. radio parts meters etc.	12 cu.
1	Box tubes (approx. 500) & parts	12
[illegible]	Power units	10
8	Gyros in large spheres (about 2ft. diam) Sg 66	15 each (Photog)
1	Cabinet with breadboard circuits	[illegible]0
1	Box radio test instruments meters	10
1	Box lab.& office equip.	10
1	Box A-4 control gear (ground)	10
2	Box misc. radio gear	6 each
2	Box test meters & equip.	10 each
1	Box telephones, rations, etc (rations removed)	10
1	Box radio gear	15
2	Power supplies	
6	Large tacks 90% empty	30 each
1	Special radio gear	10
1	BFO	
7	Power supply units	10 each
2	Pen recorders	
1	Signal generator	10
1	Breadboard oscillator unit	2

CAR-BORNE [illegible] 10450

13 MAY 1945

ITEM	NO	ITEM	NO
		1 Box D F loops	
2 Boxes meters & tubes	3 of each	1 Box radio parts	3
1 Box lab equip	2 of each	10 6 V batteries	1
1 Box tools	2 of each	1 Frequency recorder	
1 Box wire	2 of each	4 Impedance bridges	
1 Box Crystals	3	1 Box special radio gear	3
1 BFO	1	1 Basket clothes	
1 Box carborundum wheels	2	1 Box radio parts	4
1 Frequency measuring bridge	1	1 Tranreceiver	1
1 Intercom set	1	1 BFO	1
1 Radio test set	1	1 Optical device	1
2 Trayectors simulation	1 each	1 HV rectifier	4
1 3" CRT	1	1 Box documents (removed	
1 Special radio test	3	1 Box lab. parts	
1 Optical recorder	1	1 Box radio hardware	1
1 Vac. tube voltmeter		1 Box household goods 4 cu. ft.	
1 12 V Battery	1	1 Box relays	2
1 Box radio hardware	4	1 Box motors & gears	5
3 Boxax misc. radio gear	6 total	1 Box radio hardware	2
1 EW2222 /15/I (lathe like)	30	1 Box polystyrem tubing	3
1 Box cablet connectors	4	1 Traj simulator	1
2 Radio components	4 each	30 Small radio units	
1 Box radio components	3	3 Box relays	3 ea.
2 Box radio components	3 each	1 Power unit	2
5 Box radio components	2	3 Boxes relays tubes	3
1 Condenser microphone		1 Misc. radio gear	8
2 Oscil amplifiers	1 each	2 Box optical gear	30 ea
2 Tube boxes	1 each	1 Box rad	4
1 Cable connector	1	1 Lab test inst.	6
1 Special radio gear	2	1 Box radio parts	1
1 Box receiving tubes	1	1 Box cable markers	2
1 Optical recorders	1	1 Field sound recorder	1
1 Large relay rack (Photo I)	40	30 Large radio tubes	
2 Telephone switchboard 3 cu.		6 A-4 gyros	1 ea
ft. each.		1 Box optical gear	8
1 Optical EW2223 II/204		1 Box dry cells	2
40 Large A-4 radio units		1 Box meters	6
1 Box castings	1	1 Box teleph equip.	2
3 12V batteries		1 Special radio test	2
1 Box I F coils		1 recorder	1
1 Optical device		2 Box misc.	2 eas.
1 Frequency converter		1 Cam Driver resistor device for	
1 Box office equip.		voltage simulation	8
1 Optical device		1 Box CRT	3
1 Fiedl strength meter	1	1 Box condensers	3
1 Cu 0 rectifier		1 Box timers	2
1 Wide band CRT amplif.		3 Receiver-filter units	2
1 Frequensy meter		1 Large triood	
1 Sound recorder		1 Rectifier	2
1 Radio gear	2	1 Dr Rosenthal tester	1
Cu 0 rectifier			
1 Intercom	1		
1 Personal clothing			

CAR 56593..S

13 MAY 1945

ITEM	NO	DESCRIPTION
1	DmG7K	Trans-Rec. Panel (?) (May be C.M. Equip) 6 panel rack 2 R.F. connectors.
2	-	Box El. comp.
3	-	Box El. comp.
4	-	Calibraty panel (single small unit with most for repleaseable unknown units, Rebber pods)
5	FAY-S65	Small unit having 4 dials calibrated in sec. One labled Vozkommando. Purpose unknown.
6	-	Box accounting records. Time and work books for all employees.
7	-	Parts order records. One wooden box.
8	AS3298	Trans. Volke High Priority
9	EK 2234/251	Frequency Bridge
10	FKGM13710G	PPI CR Tube
11	--	Box el. components.
12	--	Box el. components incl. much oscillograph.
13	--	Monitoring rack incl. 16 panels. Purpose unknown.
14	Type ol2 N.T.R. 6	Spot frequency transmitter.
15	C-23	Matching & switch
&	O-22	units for meter were commentric with much plumbing larg units
16	--	Box electrical components.
17	--	" " "
18	--	" " "
19	--	" " "
20	--	" " "
21-28 inc.		" " "
	(14 boxes altogether)	
29	--	Box private belonging. Proffessor Schloch
30		Transmitter-Marked Beobachtungs-Stelle fur)rest scr appears to be v.h.f. transmitter. Air cooled valve.
31	--	Fair metal boxes cont. cable & measuring head (probably soundlevel ind.)
32	IDHTS52 (N.7)	Signal Gen. or wavermeter Freq. unknown. cable
33	--	Box contains addressograph printer.
34	--	Power unit
35	--	4 Panel Rack looks like Jamming transmitter.
36	--	Control & meter panel about 4'x3' no appears to be unused but completely wired.

37	1" X 1 1/2" X 2" (Peenemunde Number SW 27)	
38	21044	Large steel box with small power units.
39	--	Special purpose panel
40	S221752	
41	--	A Looks like xxxxx about 1 meter. Two units, three deloned each.
42		Box mechanical parts or figs, purpose not known.
43	--	Box electrical lab. equip.
44	LS-28	
44	EW227	Box lab equipment ime remote pressure gauge. Took one gauge out.
45	[illegible]	
45	No Nr St-116W B & C	Appear to be test panels for A-4
46		Power pack for radio transmitter.
47		Sets DMV 4K Spare parts.
48	WaA024a 11321	Telep Distribution panel.
49		Test panel for A-4 "vertipant" xx gyro & rudder
50	--	Test panel for A-4 petch gyro.
51	--	Other test panel-probably for A-4, but exact purpose unknown.
52	--	63-ti-7-BMM-Recording M.V.meter.
53	--	Combined test panel for Horizont & vertihart.
54	--	Test panel & SW Panel for Mesira I
55		Cable assembly-code name "Heidel Klar"
56		Large low-volt power pack.
57		AEG Type M3 V II & Electeonic assembly-small. Looks like I.F. Amp & com.

CAR FS ITALIA E1010731

13 MAY 1945

ITEM	NO
1 Audio Sig Gen	
1 12V battery	
1 Gyro	
1 Small Tubes	
1 Box tubes	3 cu. ft.
1 Box receiving tubes	3 cu. ft.
1 box tubes sockets	3 cu. ft.
1 " " "	3 cu. ft.
1 " Tubes	3 cu. ft.
1 Box cathode ray tubes	3 cu. ft.
1 Box Polystyrene tubing	3 cu. ft.
1 Box Laboratory equipment	3 cu. ft.
1 Box Tubes & lab. equip.	3 cu. ft.
1 Box Fibre tubing	3 cu. ft.
1 Box Air condensers	3 cu. ft.
1 Box Meters	4 cu. ft.
1 Box Wire & L.b. equip.	2
1 Box Radio hardware	1
1 Resistors	3
1 Resistors	1
2 Lab. test	
1 Signal generator	
1 Vac. tube Vm	
1 Box fibre tubing	2 cu. ft.
1 3' X 4' wired panel	
1 Box lab test instrument	2 cu. ft.
1 Box lab. hardware radio	3 Cu. ft.
1 Box lab test equip	3 cu. ft.
1 Box lab meters	4 cu. ft.
2 Signal generators	
1 Transformer	
1 Box lab equip	3 cu. ft.
1 Test inst.	
1 Box nuts bolts	3 cu. ft.
1 Wavemeter	
1 Box wire	4 cu. ft.
1 Box radio equip	3 cu. ft.
1 Box meters	3
1 Box radio equip	2 cu. ft.
1 Box aircraft generator	2 cu. ft.
1 Box tubes	½ cu. ft.
1 Box radio equip	2 cu. ft.
1 " " "	4
200 ft R.C. Cable	
1 Box resistors	3
1 Transmitter	1
1 Box radio equip	3
1 " " "	1
1 Box tubes	2
1 Roll wire	
1 Box radio gear	2
1 Box tubes etc.	3
3 Lab. test inst	
1 Box lab equip	4

1 Box wire	3
1 Box condensers resist. etc.	3
1 Rectifier	1
2 Boxes radio gear	2
26 Gyros	1 each
2 Box radio gear	2 each
1 Box temp. thermocouple	1
1 Box tubes	3
1 Box relays (power)	3
1 Cathode ray oscill	
1 Box terminals	1
1 Box plastic hardware	3
1 Rectifier	2
1 Wavemeter	1
1 Recording microamm (broken)	1
200 la ge tubes	
1 Wavemeter 50-300000KC	1
2 Elev. angle meas. equip	1 each
2 DMQ-3X tran-rec equip	20 each
4 A-4 gyros	
2 Box radio gear	4 each
Assorted loose meters generators and miscellaneous gear	20
1 Box transformers	2
1 Box connectors	4
1 Box aluminum castings	3
1 Box meters	2
1 Box misc. radio gear	2
1 Radio test set	1 each
1 Box tubes & meters	3
1 Vac tube volmeter	
1 Box small meters	2
1 Electrical recorder	1
1 Theodolyte	3
1 Magnetic tape recorder	1
1 Wavemeter	1
1 Amplifier	½
1 Box radio misc. gear	1
1 Box wire & radio gear	2
1 Box condensers etc.	1
Picks, shovels, saws, chairs	
1 Box receiving tubes	2
1 Box Ceramic tubes	1
1 Field strength meter	1
1 Box wire	1
2 Lab test units	2 each
1 Box tubes, inductances etc	2
1 Box meters	2
1 " "	2
3 Boxes radio test inst.	1 each
1 Gyro mounted in 2 ft. sphere	
1 Borad band dipole	3 cu. ft.
1 Radio test set (special)	2
1 HF sig generator	1
1 Box meters	1
1 Frequency meter	

	breadboard HF power oscil.	1
1	Box spagetti	2
1	Box wire	2
1	Box telephone equip	3
5	Intercom	1 each
1	Signal generator	
1	Box resistors	3
1	Experimental horn	3
6	Lab test instr	1 each
1	Box meters	2
3	A-4 traj simulators	1
6	Tripods	
1	Box tubes	1
2	Telephones	
1	Optical device	1

CAR FRANCE 182142

14 MAY 1945

ITEM	NUMBER	DESCRIPTION
1	Box [illegible]	Box contains 20 units [illegible] 24895, K3G/ 1221 (Field-types gear)
2	Box [illegible]	Contains about 8-10 units same as item 1.
3 (No EW No.)	Orig [illegible] 1996	First three contain
4	[illegible]	standard telephonic amplifier
5	[illegible]-142974	relay equip. Last empty. All gastight metal boxes with about 12 small chasses inside.
6	[illegible] (Add eight or 10 similar also with number EW2223)	
7	Box [illegible]	Contain many small boxes, [illegible] field type switch gear.
8	[illegible]/[illegible]-224	Private stuff name Hutse
9	No. 18	Appear 1 doz. V.R. lamps
10	No. number	P.k.h.-7011 Crate cont. Schaltuhr 11 3 of these
11	[illegible]	.1 sec to 100 sec. about 24 units [illegible]1221, 700387-Field Type switch gear.
12	Case No. 1 (Blue)	Audio amp. gear loud speaker
13	Six units not in packing	FZ 708/157904 Field-type control gear.
14	Four units in own boxes	14 step condenser network high pass filter 600 v 10,000
15	1 Unit wrapped in cardboard.	Test panel (experimental) for A-4 gear equipment
16	Box 19	[illegible] U.R. lights
17	Chest Box marked Raf Pr 2413	18 Switch units in chest not all same.
18	Chest marked Raf Pr 2413 2	Papers & apparatus possibly pertaining to measurements of VW V. in stratosphere (3 folders taken out)
19	Large grey chest EW-2252, 213/X 0	gear
20	No box or number	6 inch "Bild wareler". (eleven units)
21	EW 2224/15	About 18
	EW 2224/14 usw.	"Orthr" gerat Type IIb
22	No box or packing	
22	"	About 24 Gerat 375 Type Honvey X (Field-Type control gear)
23	"	5 Stabilized power supply units.
24	Box, no number	Much parts, possibly to make CRC Chassis.
25	Drawer marked EW2221/K40-Sacken	Box private stuff papers w/meter book. Note books belonging to Kramer removed.

Inventory of Documents Removed
From Railway Cars at Pesting

This list was taken on 14 May, 1945, and includes all documents removed from the following cars: Nord Belge KKZW 10450, French No. 182142, France SNCF KKnw 212157.

K 1 List of Cables, instruments and accessory parts with reference to some of the wagons mentioned in K 2. File.

K2 Classification and listing of specialist vehicles used for field testing. Notebook.

K 3 Notes of telephone conversations, many with firms on delivery of apparatus etc. Contains cable assembly for wagons PrI, PrII, Absch T., Panz, FR, etc. interconnection. Folders, loose papers.

K 4 Requisitions, orders, deliveries. Mostly cable. Loose folder

K 5 List of addresses and telephone numbers of various firms. Probably belonged to order clerk. Notebook.

K 6 List of orders. Notebook with loose papers in it.

K 7 Labour lists. Notebook with loose papers.

K 8 Orders, deliveries, and memoranda relating thereto. Ring file.

K 9 List of correspondence and telegrams, probably belonging to radio or electrical stock-keeper. Notebook.

K 9a Same as K 9 on general equipment. Notebook.

K 10 Stock-keeper's letters and memos to suppliers. Folder, loose papers.

K 11 Notebook of travel permits, loose papers relating.

K 12 Small file, letter registers, destruction lists, parts loading plan for wagons mentioned in K 2.

K 13 Progress charts, order, materials, supplies. Folder, loose papers.

K 14 Shop orders and deliveries. Ring file.

K 15 Drawings and parts lists for Ziegelsteinsender. File.

K 16 Production schedules, Ziegelsteinsender. File.

K 17 Production correspondence, Ziegelsteinsender, File.

K 18 Technical abstracts, Siemens-Halske Tech. Library. Bound book of mineographed pages.

K 19 Correspondence and memos relating to Mot III. Contains originals to Fa Geyer u. Sohn. No names of persons on our lists. Folder, loose papers.

K 20 Same as K19.

K 21 Private notebook apparently belonging to expediter by name of Lammy (?) whose signature frequently appears in K19 and K20. Bound notebook.

K 22 Inventory lists 7040/ Los 2 etc. Folder loose papers.

K 23 List of firms and addresses. Folder, loose papers.

K 24 Lists of parts and requirements for wagons, K 2. Folder, loose papers.

K25 [illegible] lists and correspondence relating to expediting of wagons. Folder, loose papers.
K26 Same sort of thing.
K27 Correspondence and instructions relating to ARP. Folder and loose papers.
K28 Orders and relating correspondence. Folder, loose papers.
K29 Letter register. Bound book.
K30 Instructions to and signatures of couriers. Folder.
K31 Doctorate dissertation by Walter Schwidetzky, Berlin Tech. Hochschule, 1941. Ring file.
K32 Technical folders on measuring apparatus, mostly Phillips. Also contains loose letter by Dipl. Ing. Grötrup on radio measurements of interference caused by A4. Folder loose papers.
K33 Lists of materials delivered with Wareneingang numbers. Folder, loose papers.
K34 List of cables for Mot III. Folder, lo se papers.
K35 Letter register, small notebook.
K36 Note book of Kramer, details of some radio equipment incl. Messina II. Also loose papers.
K37 Misc. papers, bills etc. connected with Geyer and Son.
K38 Specifications and digrams of testing apparatus for Buchhold's accelerometer. Stotz Eberbach. Folder.
K39 Drawings for Ventilkasten. Large hydraulic valve box which might be used for static testing or ground control of "A-stoff" rocket. Folder and loose dwgs.
K40 Stock lists for Kommandopult, Stromversorgung, etc. 3/a, 3a/c, 3/a+c, etc. Folder, loose papers.
K41 Lists of material for Ventilkasten (K39) and others. Folder, loose papers.
K42 Parts and material lists, and drawings for cabling, probably A4. Box of loose papers.
K43 Circuit diagram and discription of 30 volt power supply. Folder.
K44 Records of deliveries of machine tools to HAP11. Name on folder Fühlendorf. Also loose sheets.
K45 Correspondence relating to work of EW229 and EW 2252. Folder, loose papers.
K46 Folder with packingslips, papers and correspondence relating to dispersals and factories, including Dernau/Ahr and others. Folder, loose papers.
K47 Dispatch book, letters. Bound book.
K48 Notes and manuscript on stability of rocket, from servo point of view. Shows tiny sketch of winged rocket launched vertically. Folder with loose papers.
K49 Register of correspondence. Folder loose papers.
K50 Fühlendorf notebook of truck loadings. Small bound book.
K51 Organization and personnel records of EW 2252. Folder, loose papers.
K52 Administrational papers of EW2252. Contains records of developments of new measurement instruments by various members of group. This later has name Bangerter on front.
K53 Wagon loadings, evacuation. Folder, loose papers.

K54 List of apparatus requiredfor "Bauwerke 21". Folder loose papers.
K55 Delivery notes and specifications for HF equipment includeing "Honnef", "Ortler", and "J-Geräte". Folder, loose papers)
K56 Notebook, containing rough notes of Bangerter. Mentions A4, motorized troops, Prof. Buchhold, etc.
K57 Outline of accounting procedure, Emw. Decimal key. Small bound publication.
K58A Lists and drawings of Wehrmacht HF Kables. Envelope.
K58B Same.
K59 ADV transformer lists. Folde .
K60 Technical notebook (rough) by Friedl. Mentions M3, FS,
K61 Instruction book for radio truck installation including dezimeter, 7 mc, impulse equipment, the purpose of which is unknown. Title is "Bodenstation, Potsdam-Berlon".
K62 List of about one hundred contracts for raw materials and parts, giving the name and address of the contractor. Some relating correspondence. Connected with Wa Prüf 10. Folder loose papers.
K63 Order on Firma LGW for relays and tel. equipment and related papers.
K64 Lists of buildings, drawings of test apparatus for cable, inventories, and in particular a drawing of the overall plan for "Liegende u. stehende Prüfung" of rocket similar to A4, dated 10.7.44. Folder loose papers.
K65 Wagon loadings and inventories relating to dispersals EW2252 was apparantly at Neppermin in Setp. 44. Envelope loose papers.
K66 Catalogs radio parts. Envelope.
K67 Folder of Dipl Ing. Wackernagel with letters and lists of laboratory equipment.
K68 Order book and invoices. Bound book with loose papers.
K69 Stock lists and related papers, EW22. Folder loose papers.
K70 Published list of vacuum tubes and sockets with ratings. Envelope.
K71 Folder of quotations and bills. Some personal stuff. Folder loose papers.
K72 Order forms for transformers. Folder.
K73 Organization of EW. Folder. (Extremely valuable)
K74 Lists of equipment and related papers. Includes drawings of Prüfgerät für LGW Lichtleiter. Folder loose papers.

K75 Drawings of Heideprüfgerät I and other pape s relating to priority of supply of test equipment. Folder loose Papers.
K76 Design details of Siemens polariyed relay. Folder with Friedel's name. Loose papers.
K77 Transformer designand test data. Folder, loose papers.
K78 More transformer design data. Folder loose papers.
K79 Diagram and description of 7000 cps tuning fork standard fre uency generator. Folder, loose notes.

K80 Treatise on theory of broad band amplifiers. No name or date. Bound volume of 97 pages.

K81 Diplom-Arbeit Hans [illegible]schmann. General considerations for the generation of high-voltage DC. Bound volume 45 pages.

K82 Elementary diagram for FR-Batt mot.II. Appears to be complete diagram of ground equipment for A4 firing and testing. In folder.

The following list was taken on 13 May, 1945, and includes all documents removed from the following cars: F S Itàlia E1010731, Oppeln 5659 Grs.

S 1 Organizational material incl. org chart for EW22 with names. Paper bound ring folder, loose papers.

S 2 Accounts and Notes relating to administration of EW§. Folder, loose papers.

S 3 Rules for conduct of Correspondence dated 31.7.1944. Folder.

S 4 Complete organization of EW as of 1.8.1944. Folder loose papers.

S 5 List of firms supplying Peenemunde Ost. Folder loose papers.

S 6 Notes on purchase of apparatus and materials. Folder loose papers.

S 7 Story of A4 development in monthly reports and general notes. Folder loose papers.

S 8 Notes of Helmuth Pfaff. Card index of literature he was interested in. Envelope with folder and cards inside.

S 9 Two notebooks referring to A4, A5, and various electrical sub units. In envelope.

S10 Mathematical Analysis of Range Control. By Steuding. Unbound memo, Archiv 87/166 g Kdos.

S11 Fundamental curves and data for Range Control studies. Also two copies of story of evacuation of Darmstadt. Folder loose papers.

S12 Schwidetsky's private note book, 1944. Small black book.

S13 Instructions etc. for dispersal of EW2232 to Oberkaufungen. Folder.

S14 Notes, probably of Schwidetsky on administration of 2232. Folder.

S15 Notes, probably of Schwidetsky on administration of 2232. Folder, loose papers.

S16 Lists of Isar Geräte recieved and dispatched. Also some general dispatch notes. EW 2232. Folder.

S17 Misc. Technical papers relating to I, Inns, and Isar geräte. Loose papers tied in a bundle. (Were found scattered about in cars and boxes.)

S18 Papers relating to Messkopfprüfgerät, Isar and Inngeräte, and Messina II. Mixed correspondence. Folder, loose papers.
S19 Records of telephone conversations between Stuhlinger and various firms regarding I-Geräte. Folder.
S20 Drawings and Specifications for BMK1. Stotz, Eberbach. Folder, loose paper.
S21 Papers relating to details of expediting and testing of I, Isar, and Inn Geräte. Not of technical interest. (Found loose. Put in envelope)
S22 Contents of boxes marked for CW 2232. File.
S23 Letters (outgoing) relating to Isar and Inn Geräte up to 15.2.45. Folder.
S24 "Ranging errors which would have occurred to date in firing trials using velocity cut-off with and without time correction. 27.12.43 by Schwidetzky. Unbound paper of 47 pages, Archiv Nr 119/4 gk.
S25 Description of 50 cps Frequency generator controlled by pocket watch escapement and photocell. Developed by Prof. Buchhold. Folder, loose papers.
S26 Notes on Timing switch, Schaltuhr II and 50-cycle generator. Folder, loose papers.
S27 Schwedetzky's file on BMK. Correspondence with Stotz etc. Folder, loose papers.
S28 Reports on various range control devices: Isar, Inn, Querintegr. and thrust regulating devices, dated 15.2.45.
S29 Very complete calculation and plotting of velocities accelerations etc. during the Brennschluß period. Also other trajectory data. Papers by Steuding and Strobel. Folder.
S30 Notebook, much of it in shorthand, possibly belonging to Horn. Some loose papers.
S31 Notebook, mostly shorthand, references to Honnef I and II.
S32 Diary either of Schwidetzky or Stuhlinger, refering to every aspect of work carried out on BMK. Correspondence with Prof. Wagner, Prof. Buchhold, Stotz Eberbach, etc.
S33 BMK. Adjustment of measuring head and connections to circuit. Instructions by Stotz Eberbach. Notes on Isar.
S34 Details of testing and calibration devices for BMK.
S35 Collection of Reports on meetings regarding Isar. Dr. Stuhlinger's. Folder loose papers.
S 36 Specifications of Stabipla and Inn. Stuhlinger 15.2.45. Folder.
S37 Drawings and test sheets for BMK. Folder.
S 38 Trajectory calculations and plotting of test shots V4 to V40 18.9.43 (A4 rocket)
S39 Report by Stuhlinger on Buchhold Innenschaltgerät. Work done at Darmstadt. Folder, loose papers and dwgs.

S40 Technical specifications for electrical components. Dated 5 Oct. 1944

S41 Letters recieved concerning Isar and Inn. Stuhlinger. Folders

S42 Circuit diagram for I-gerät 1 and I-gerät 2. Folder.

S43 Latest wiring diagrams for Isar, Inn and accessory devices.

S44 Documents relating to Prof. Wagner's cell, including full descriptive report by Prof. Wagner. Folder.

S45 Kirchstein's folder on range errors and thrust control. Folder.

S46 Technical specifications for electrical apparatus. Date 5.10.44, Folder.

S47 Notebook of sketches and rough notes, mostly in shorthand. Folder.

S48 Notes on Isar and messkopfprüfgerät. Folder.

S49 Notes on investigations of Isar and Messkopf accessories.

S50 Report by Stotz Eberbach dated 27.12.44 on circuits of BMKl. Unbound report.

S51 General notes by Stuhlinger, range control and devices. File dated 5.5.43.

S52 Notes on BMK. Folder.

S53 General notes conferences etc. on Isar, and Inn. Stuhlinger, 15.2.45.

S 54 Range control. Reports on various methods and devices. Folder with loose papers.

S55 Specifications and notes on Isar Netzteil. Folder, loose papers.

S56 Calibration of IG2 and Netzteil details. Folder, loose papers.

S57 Details of Messteil (for I-gerät) made by Lorenz. Folder loose papers.

S58 Detail report on Innenschaltgerät, with photographic illustrations. Small pamphlets

(The above list of documents which carry "S" numbers were either in a broken cardboard box, or loose in the care)

CONTENTS OF CHEST MARKED "A".

File 1. Specifications (Deutsche Normen)
2 Ditto
3 Ditto
4 Ditto
5 Ditto
6 Ditto
7 Ditto
8 Ditto
9 Ditto
10 Radio specifications.
11 Rough notebook, almost entireely illegible belonging to BÖHM.
12 Post book for EW 5113
13 File of financial papers.
14 Administrative papers
15 Works circular letters of EW from 1-8-44 to 6-2-45
16 Administrative and binding letters.
17 Administrative notices.
18 Administrative and disciplinary circulars.
19 Orders for stationery
20 List of employees and their dispersal points at BLEICHERODE. (incl. some personal data.
21 File of calling-up papers for workers at EW Karlshagen.

Chest "A" also contains some misdellaneous stationery.

CONTENTS OF CHEST MARKED "B".

File 1 Calibration charts of labobatory instruments.
2 Technical notes including eletrical data.
3 Top secret data curves for A4 including velocity curves, and acceleration curves, (removed from chest).
4 Papers on "Brennschluss" and thrust regulation with I-Gerät.
5 Instructions for use of Ida-Gerät.
6 Oscillograms relating to firing trials.
7 Part list of the S-Gerät.
8 Tables of figures.
9 Circuit diagrams for Ida-Gerät.
10 Differential pressure gauge for telemetering; transformer data.
11 Administrative papers EW 2283.
12 Design of HF transformers
13 Details of modifications to Rel sand 2009.
14 Remarks on the range tables for the sbV Gerät.
Effects of various alterations on the range of the A-4.
15 Description of the Buchhold integrating accelerometer.

CONTENTS OF CHEST "B" CONTINUED.

File B 16 Photostat copy of article in "Physikalische Zeitschrift" for Feb. 15th 1943. on a high resistance bolometer.

17 Papers on the "Erstling-Gerät" aerial (FuGe 25 A).

18 Papers relating to electrical rudder motor. (drive).

19 Wiring schedule and test data of I-Gerät: inventory of electical instruments on charge to Ing. Horn.

20 Description of cathode ray oscillograph.

21 Information on iron cored filter coils.

22 Drawing office number books.

23 Ditto.

24 List of secret letters.

25 Top secret report on errors in range with the Buchhold accelerometer. 2. Errors in range with simple integration.

26 Circuit diagrams of apparatus carried on the rocket.

27 Results of 14 firings of A-4 to test accelerometers under operational conditions.

28 File of destruction certificates.

29 Odd workshop sketches.

30 List of numbers, possibly drg. nos.

31 Test schedule for unidentified apparatus.

32 Drgs. and circuit diagrams for various accelerometers.

33 List of secret & top secret docs. Grp. III Minutes of meeting to discuss specification of Iller-Gerät III. Note on suppression of Verdoppler before start of rocket. Report of type approval tests at Peenemuende of 24 production models of Iller-Gerät. Correspondence between Peenemuende and Zeiss-Ikon about Iller-Geräte. Minutes of meeting on testing of I-Geräte. Paper on vibration measurement in Geräteraum of A-4. (Signed by Kirschstein Horn and A!N! Other.

34 File of firing trial reports (9 & 10 1944.).

35 Circuit diagrams I-Gerät. Test and operating instructions for I-Gerät.

36 Collected drgs for I-Gerät.

37 MS draft report on thrust regulation.

38 AEG frequency meter: desdription & instructions.

39 Obsolete circuit diagrams.

40 Photostat of paper on a magnetic amplifier by Buchhold. Other technical papers.

Seventeen oscillograph records of programme timing in A-4.

41 Miscellaneous technical papers, including some circuit diagrams relating to I-Gerät.

42 Test data for I-Geräte.

43 Secret and top secret circulars.

44 Top secret papers on 1. Present condition of radio controlled "Brennschluss" 2. Course correction by time correction on the "Brennschluss" apparatus.

45 Papers on rudder shaft design.

46 Drawings of wind tunnel models

CHEST MARKED "C" CONTAINS FINANCIAL PAPERS ONLY

CHEST MARKED "D" CONTAINS OBSOLETE TECHNICAL AND ADMINISTRATIVE PAPERS!.

Chest Marked "E" contains a library of technical publications and books of late date, having considerable technical interest.

Documents cataloged and investigated by the following:

F/Lt. Stokes
S/L. Sharpe
F/Lt. Kenney
Dr. R. W. Porter
Dr. Golin

A BRIEF SURVEY OF GERMAN CONTROLLED MISSILES

The material presented in this report, unless otherwise indicated, has been obtained from captured documents and may be considered reliable. However, it is far from complete and may include many signs of omission.

Owing to an acute shortage of vacuum tubes (the result of industrial target bombings) the production of controlled missile requiring more than two tubes per unit was stopped. However individual laboratories were encouraged to continue development work so long as private stocks of tubes were available.

General difficulties experienced with transportation, production and development recently led to the abandoning of all [1]Flak rocket projects. Of the many controlled missile projects active in a research status only two were being seriously considered for possible use. These were the X-4 (8-344), and the Schmetterling (8-117). However, since research work was continued on remaining projects, the information available at present concerning such projects is included in this report.

It is to be noted that with the sole exception of FX, all of the German guided missiles utilized rocket drive in one form or another.

This report will be divided into three sections:

I. The [2]Flak rocket -- A. A. missile launched from the ground.

II. The Air to Air missile.

III. Homing equipment and fuses.

<u>Section I</u>:

The ground launched controlled missiles are:
Wasserfall, Rheintochter 1, Rheintochter, Enzian, Schmetterling (8-117), FK25 (Feuerlilie), FK55.

1. Quoting Dr. Osenberg
2. Information obtained verbally from Dr. Osenberg.

TRANSLATION

High Command of the Luftwaffe, Chief of the Technical Air Armament Group for AA development of air armament.

FLAK--E4/B Az. 140 No 194/45 Secret

Number of tests

Type of Device	Total No.	Without Control	Preset Control	High-Freq Control
Schmetterling				
(a) Projected from ground	59	2(1)	-	57(31)
(b) Launched from aircraft	21	-	1(1)	20(6)
Enzian	24	24(15)	-	-
Rheintochter	88	42(16)	21(8)	25(5)
Mod. 3	7R			
Wasserfall	28	1(0)	-	27(10)

Numbers in parentheses indicate tests at which stability, driving gear, or control failed.

By order

TRANSLATION

"WASSERFALL"
Speed Range: Supersonic
Developed by: Elecgromechanische Werke
Dimensions: Length 783 cm. Span 251 cm. Diameter 88 cm.
Weight: Empty 1310kg. Fuel 360 kg. Liquid O_2 1500 kg.
Compressed air 65 kg. Explosives 305 kg. Launching 3540 kg.
At target 1615 kg.
Launching: Vertical
Total Impulse: 360,000 kg. sec.
Starting force: 8000 kg.
Speed at target: 45 seconds.
Intelligence: Infra-red homing.

Enclosure 2
For OKL/Chief TLR/AA - E5/B Az. 101a No 196/45 Secret
Development status of Wasserfall:

(a) Tests:
Twenty-five test models were fired of which twenty-four were with remote control installed. Propulsion gear difficulties encountered at first have now been eliminated.

(b) General development status:
By and large no difficulties exist as to the fuselage. There are two controls (servo), one hydraulic and the other electric, in the development stage. Neither investigation has as yet been concluded. The problem of protecting the fuel tanks against corrosion can be regarded as solved. Additional tests in this field are still being conducted.

RHEINTOCHTER 1"

Operating Speed: Above and below sonic.
Developed by : Rheinmetal-Borsig
Dimensions: Length 630 cm.
Span 275 cm.
Diameter 54 cm.
Weight: Empty 76 kg
Second stage 650 kg
Main Jet 220 kg. (powder)
Explosives 150 - 100 kg
Launching weight 1750 kg
Weight at target 750 kg
Launching impulse: 80000 kg. sec.
Launching attitude: Angle
Launching thrust: 65000 kg
Velocity at end of burning: 1300 km/hr.
Velocity at Target: 1080 km/hr.
Second-stage rocket: one dry powder
Second-stage impulse: 40,000 kg sec.
Second-stage burning time: 0.6 sec.
Second-stage thrust: 65000 kg.
Main-stage burning time: 10 sec.
Intellegence: Remote radio control

"Rheintochter 3"
Speed Range: Above and below sonic.

Developed by: Rheinmetal-Borsig.
Dimensions: Length 500 cm.
Span 313 cm.
Diameter 53.6 cm
Empty 25 kg.
Starting stage 440 kg
Main stage fuel 88 kg
Main stage O_2 336 kg
Main stage air 18 kg
Explosives 160 kg
At launching 1570 kg
At target 685 kg
[illegible]
Launching attitude: angle
Total launching impulse: 105000 kg. sec.
Launching thrust: 26700 kg
Velocity at end of burning: 410 M/sec.
Velocity at target: 400 to 200 M/sec.
Assist rockets: two dry powder rockets.
Assist rocket impulse: 25000 kg. sec.
Assist rocket burning time: one second.
Main jets: Liquid rockets, pressure feed.
Impulse: 80000 kg. sec.
Burning time: 45 seconds.
Thrust: 1700-2300 kg.
Intellegence: Remote radio control.

Enclosure 3

For OKL/Chief TLR/AA - E5/B Az. 101a Nr. 194/45 Secret

Development status apparatus Rheintochter:

(a) Tests:

Of the first development model R1, 82 were fired of which 22 had remote control. Among these four failed. Of the second model "R/3" several were launched some with powder, some with liquid as the main power. Remote control was not used.

(b) General development status:

The control used in the apparatus Rheintochter has proven satisfactory. The control signal transformation (resolving of the control signals into components corresponding to the instantaneous roll position) has also worked satisfactorily. Fundamental difficulties of remote control should be no longer encountered.

The starting drive and the main drive of apparatus "R3" will have to be investigated anew. Otherwise the fuselage and the control which had been tested in the "R1" apparatus have been incorparated. Production schedule has not yet been planned.

"ENZIAN"

Speed range: Subsonic

Developed by: Holzbau-Kissing, A. G.

Dimensions: Length 365 cm.
Span 400 cm
Diameter 90 cm.

Weights: Empty 390 kg.
Assist take off 320 kg.
Main rocket fuel 105 kg.
Oxygen 455 kg.
Air pressure T-Stoff 35
Explosives 300 kg.
Launching weight 1600 kg.
Weight at target 690 kg.

Launching attitude: angle
Launching impulse: 124000 kg. sec.
Launching thrust: 6000 kg.
Velocity at end of burning: 270 M/sec.
Velocity at target: 250 M/ sec
Assist take off: four dry powder rockets
Assist impulse: 24000 kg. sec.
Assist burning time: 6 sec.
Assist thrust: 4000 kg.
Main power: Liquid rocket-pump feed.
Main power impulse: 93000 kg. sec.
Main power burning time: 62 seconds
Main power thrust: 1000 to 2000 kg.
Intelligence: not decided.

Enclosure (4)

For OKL/Chief TLR/AA - E5 Az. 101a No 194/45 Secret.

Development status apparatus Enzian.
(a) Tests:
Twenty-three test models were fired all without remote control, and with an auxilliary driving gear (assisted take-off units).
(b) General development status:
For apparatus "Enzian" two propulsion units are in a stage of development; one propulsion unit with pressure feed (VFK), one with pump feed, (Firma Walter, Marklissa). The VFK propulsion unit (Vierjahresplan Insthrut Fur Kraftfahrzeuge) is exeepting minor changes, the same as the one which is used with the Rheintochter 3". Flight tests with both propulsion units still remain to be done. The control of the apparatus is still in a very hazy stage of development. Production schedule has not yet been planned.

"SCHMETTERLING" S-117

Operating speed: below sonic.
Developed by: Heinkel Flugyeus Werke
Dimensions; Length 429 cm.
Span 200 cm.
Diameter 35 cm.
Weight: Empty 150 kg.
Assist take off 180 kg.
Main power fuel 13 kg.
Main power O_2 60 kg.
Compressed air 3kg.
Explosives 25 kg.
Weight at target 175 kg.
Launching weight 430 kg.
Launching: angle.
Launching impulse: 26000 kg. sec.
Launching thrust: 3400 kg.
Velocity at end of burning: 240 M/sec.
Velocity at target: 240 M/sec.
Assist take-off: two dry powder rockets.
Assist impulse: 13600 kg. sec.
Assist thrust: 3400 kg.
Assist burning time: 4 seconds.
Main power: Liquid rocket with pressure feed.
Main impulse 12500 kg. sec.
Main thrust: 380 to 60 kg.
Main burning time 57 seconds.
Intellegence: Radio remot e control.

Enclosure (1)

For OKL/Chief TLR/AA - E5/B Az 10A No. 194/45 Secret.

Development status Apparatus 8-117

(a) Tests:

Many test models were fired, of which 20 were launched from aircraft. Of 47 models fired from the ground with remote control, 20 were satisfactory, while one part of another failed in 27 models.

(b) Production Schedule:

Start of production is planned for March 1945. By and large, production of the fuselage can go ahead, although there are still wind-tunnel and development test in progress. As to the propulsion gear, there are still considerable difficulties necessitating further tests. Due to insufficient planning on the part of the firm BMW a delay of three months in the production schedule is unavoidable. Control no longer presents basic difficulties. Certain questions regarding the generator are being solved. Tests with various intervalometers have started. Results can not yet be judged.

SECTION II

The air-to-air controlled missiles are:

Hs 298
X-4 (S-344)
Hs 117-H
Fx

Hs 117-H is same as Hs 117 except equipped for aircraft launching. (This information is not reliable).

Hs 298 (S-298)

Operating speed: Sub-sonic.
Developed by: Henschel Flugzeug Werke A. G.
Dimensions: Length 254.5 cm.
Span 124.7 cm.
Diameter 25 cm.
Weight: Launching 120 kg.
Explosive 48 kg.
Assist unit 33 Kg.
Speed (horiyontal): 240 M/sec.
Maximum range: 3.5 km.
Minimum range 0.6 km.
Ceiling (above launch): 1.3 km.
Main rocket: dry powder.
Thrust (launch): 350 kg.
Thrust (afger 0.6 seconds): 175 kg.
Thrust (after 0.6 xxxxxx seconds): 50 kg.
Thrust duration 31 seconds.
Fuse proximity
Intellegence: Remote radio control.
Has two channels, single jet engine.

CONFERENCE REPORT NO. 6 Berlin 19. 1. 45 Secret

Apparatus S-298 - Summary

The firm's investigation of the last fuselages 298 Mark I was interrupted because numerous changing disturbances in the function of the component parts lead to very unsatisfactory results, and because no new information could be expected regarding further and development and investigation of Mark III

In order to lay the foundation for the investigation and to gather general experience in launching tests of the Mark II series, the ED 1 Karlshagen has independently begun flight and launching tests.

The investigation of the MK II fuselages have not yet been started because delivery difficulties (of fuselagees) necessitated a delay of approximately six weeks. As a consequence, the total investigation is subject to an equally lengthy delay.

In summarizing the situation it can be said that as to development and test no new points of view and no progress have resulted since the fifth conference.

X - 4 S-344

Developed by: Ruhrstahl A. G.
Length: 190 cm.
Span: 58 cm.
Launching weight: 70 kg.
Weight at end of burning: 60 kg.
Speed at 6500 meters: 250 M/sec.
Burning time: 30 seconds.
Cruciform interdigitated mid-wing symmetrical rocket with a spoiler control on the tail.
Intelligence: Wire control or acoustic homing.
Fuse: acoustic fuse.

CONFERENCE REPORT NO. 6 Berlin 19.1.45 Secret.

Apparatus S-344 Summary (X - 4)

During the time since the last conference the apparatus S-344 stood on the threshhold of a change-over from experimental production to production. Difficulties, to be expected in this matter, especially as to the propulsion unit and the control wire coil, were considerable and in conjunction with unfavorable weather conditions delayed the investigation.

The first projectiles with stabilized (lagestabilisiert) equipment showed promising results; however, as regards control there are still difficulties to be solved. For the purpose of investigation of aerodynamics of control and propulsion unit behavior and for the purpose of considering it as an apparatus possibly to be used, the wire control method will (despite an unfavorable stand take by the G. d. J.) be further considered.

The cooperation between the development firm, the EdL Karlshagen the scientific institutes and allied firms was made difficult expecially because of the location of the firm Ruhrstahl in the west and because, as a consequence, communication and transport facilities were bad. These difficulties would have been considerably lessened and development work would have been expedited had the directerate of Ruhrstahl A. G. obeyed the order issued 11-12-44 by the Armament Staff to shift the location of the Works V and of the firm Brinkmann.

SECTION III

HOMING DEVICES, BEAM CONTROL, AND PROXIMITY FUSES

Much development work was in progress in Germany concerning "3ielsuch Gerate" or target seeking equipment. There is no evidence at present that any complete homing systems were ever tested in flight.

Control Type	By	For
Optical homing 3Km. range	ELAC(Electro-Akustik Dr. Hecht (at Kiel)	S-117
Infra-red homing (Gerate Hamburg)	ELAC Dr. Kutscher	Wasserfall
Optical homing	AEG (Allgemein Electrische Gesellschaft) Dr. Pilgers	FX 1400
Infra Red Homing Gerate "Armin"	ELAC Dr. Kutscher	S-298
Infra-Red Homing	Rheinmetal-Borsig Ob. Lt. Trankelfert	Rheintochter
Infra Red Homing	AEG Dr. Orthuber	Wasserfall
Infra-Red Homing	Dr. Alfred Kapke	Enzian
Radio Beam	Reichspost	FX-1400
Infra-Red Optics	Leitz	Wasserfall
Acoustic Homing	ELAC Dr. Hecht	Hs-117
Acoustic Homing	ELAC	X-4

Concerning these equipments the following information is available:

ARMIN-2
Rotating mirror infra-red system.
Mirror speed 16 cycles.
Weight: 10-25 kg.
Diameter 25 cm.
Tubes: 6
View angle: 45 degrees.
Range: 1200 to 1900 meters
ELAC infra-red photo cell good to 5 mu.

Rheinmetal-Borsig Project (I.R.):
Range: 3000 meters
Accuracy: + or - 0.5%
Cover Name: Gluhwernchen"
Personnel: Dr. Riedel, Mr. Hackenberg.
Location: Breslau-Hundsfeld.

Many radar monitored, radio controlled projects were under consideration as well as optically monitored schemes. So far as can be determined at present none of these schemes had reached the flight test stage. A Telefunken laboratory (Kletlenburg-lisbenrode, Dr. Enno Bussmann) was doing research on beacon transmitters micro-wave control links and directional beacon receivers. Work was in a primitive stage and the wave-lengths under consideration at this laboratory were greater than 20 cm.

Much effort has been expended in Germany on the development of acoustic proximity fuses. One such fuse has been worked out by the Rosenthal-Isolatorin G.mb.H. located at Selb, Bau. Bayreuth. This particular fuse operated on an echo-sounding principle, and contained acoustic and electronic filters for the purpose of removing undesired sonic disturbances. The range is between 20 and 100 meters and has been verified by dropping bombs equipped with such fuses. This testing was performed at Rechlin. No evidence of any large production of these fuses has been discovered.

Proximity fuse.

Firm: Rosenthal-Isolateren G. m b. H. Selb, (Gau Bayreuth), Postal number 13a, section development and Research, competent authority, Dr. Zeigler, tel. Selb 644, FS A-06 281, telegraph address, Rosenthalisola Selb.

Code Name: not given
Procedure:
(a) Working principle. The development concerns itself with the creation of a ground proximity fuse for launched missiles flying bombs over 250 kg. by means of an acoustic echo sounding procedure.

The bomb has a strong sound generator which is impelled during the fall by the air current. The sound (from the generator is reflected from the ground with a frequency increase corresponding to the Doppler effect, is taken up by a microphone attached to the bomb and is used by means of an amplifier for the realease of an electric fuse pallet. For details regarding the working principle and the progress of the development work so far, we ask you to refer to the attached report No. 503/43g dated 17-8-43 of the Munitions Commission of the Reichsminister for Armament and War Production.
(b) Definitely established range.
According to measurements made so far as to the sound intensity of the source of sound and as to the reflection of sound waves of lower frequency against ground surfaces, a fuse proximity of about 20 to 100 meters has been established.

Sensitive parts of the Body and how they are attached.

As sensitive microphones are used which are installed in special sonden places at the tip of the bomb. Heretofore electromagnetic earphones of the type HS3 employed by the Luftwaffe were used, and the desired frequency passage (filter) in the range of 650 to 750 Kc was obtained by means of acoustic and supplementary electric filters.

Disturbance possibilities.

(a) Natural disturbance influences. As natural disturbance influences can be considered noises, e. g. detonation of AA grenages, there exists, however, the possibilitye to make the release of the fuse dependent on the minimum duration of the effectiveness of the noise in the passage region of the microphone, so that failures of fuse release caused by detonation noises of short duration can be avoided.
(b) Disturbances caused by the body itself. Such disturbances are noises inherent in the body, body sound, and concussions. Their effect can, however, be eliminated to a very great extent if use is made of measurement data gained in the field of inherent sound creation of falling bombs in conjunction with a corresponding tuning of the sensitivity of the fuse.
(c) Disturbances caused by the enemy. Enemy may cause disturbance by the use of noise generators. Noise generators which are installed on the ground and which cause sound of an intensity of about 100 m., require an extremely high energy xxxxxxxxx so that their installation on a large scale on the part of the enemy would hardly seem possible. More dangerous are Healgranaten and similar noise producing apparatus which are projected agains bombs fitted with proximity fuses. Elimination of these disturbances would be possible to a certain degree if, instead of the continuous sound source of the bomb heretofore provided by development work, and impulse sound source were to be implyed. Ref. above mentioned report of the Munitions Commission.

(6) Status of Development

(a) Result of experiments. Suitable fuses in many variations have been developed and are being investigated. The first projections which took place at the end of last year at the investigation place Rechlin, produced ignitions which had to be evaluated as Lufterengpunkte and not as release by means of the acoustic echo. Investigations of the cause of this premature ignition lead to the deduction that because unsuitable (not sufficiently protected) wire arrangement between the apparatus installed on the bomb caused self acting excitement of the amplifier and therefore release of the fuse pellet.

New functional tests could not yet be made because of bad weather conditions during the past weeks and months. They are planned to take place soon at the investigation place (flight staff engineer Dr. Muller). Suitable fuses and microphones sonden including filters are ready.

RWP

Liquid Rocket Fuels----A Summary
Lt. Col. G.J. Gollin & H. A. Liebhafsky

The object of this report is to summarize briefly and (necessarily) from memory the general situation regarding German liquid rocket-fuels as we know it today. Familiarity with AI 2g Repot No. 1768 by S/L Heath, 18 April 1945, will be assumed. Since that report was written, we have interviewed the fuel experts [illegible] from Hepll, and visited BMW near Munich, and one of us (H.A.L.) has written 4 short CIOS reports from Munich on targets investigated there.

Oxygen and Alcohol Even though it gives the highest specific impulse, liquid oxygen and alcohol appear to be losing ground as against the newer fuel combinations discovered below. Although liquid oxygen and alcohol were still to be employed in A-9 (the super A-4), the feeling was growing that the physical difficulties (evaporation, freezing of working parts, supply, inability to store the loaded missile) associated with liquid oxygen are more serious than the chemical difficulties associated with other fuel combinations. It still appears to be true, however, that fuel combinations including liquid oxygen are the best suited for initial study by investigators with no previous experience in the field; Hap discarded liquid oxygen for "Gerat Wasserfall" because this missile was to be capable of being stored fully loaded.

Nitric-acid Fuels Self-igniting fuel combinations in which nitric acid is the oxidant have been gaining in favor; it is often considered desirable to add a catalyst such as $FeCl_3$ to the acid, and 10% sulfuric acid is also sometimes added (at slight reduction in specific impulse) for reasons of economy and to reduce corrosion.

Dr. Nemeoath of BMW claims to have "invented" these fuel combinations; so do various other people. Dr. Nemeoath is exceedingly enthusiastic about them. He admits that none has ever been used operationally but maintains that successful operational use was a foregone conclusion. Dipl.chem. Heller of Peenemunde also believed strongly in these fuels.

Ignition delays with nitric acid fuel combinations are likely to be dangerous owing to the possibility of forming explosive nitration products. Explosions from this cause seemed to be fairly frequent at BMW and often wrecked combination chambers. Of course a great many experiments were no doubt run there; Dr. Hemesath claims 6000 fuel combinations were tested, but this figure would seem to be high. Dipl.chem Heller mentions that several hundred were investigated at HAPAL; there seems to have been no great amount of ignition trouble at the latter station, where a nitric acid fuel combination was selected for "Gerat Wasserfall" and for "Taifun".

Aniline or a similar compound is usually added to the fuel in order to make nitric acid fuel combinations self-igniting. Certain substances added to aniline give combinations that ignite more readily with the acid used (usually Misch saure, 10% H_2SO_4) than does aniline alone. Visol, ethyl vinyl ether is such a substance. Effective fuels are therefore compounded from aniline and visol; 10 to 20% of the former, and about 50% of the later being a good combination. What else is added is not so critical, benzol, xylol and"optol" are the additives that make "optolin", which seems to be a favored fuel with Peenemunde. Optolin was orginally compounded mainly with availability in mind, for the German fuel situation was becoming critical. Its specific impulse differs little, if any, from that of similar combinations, in fact, any material that reacts well with nitric acid seems to give about the same specific impulse. The density of optolin is rather high, which is an advantage. The optol is a wal tar product that contains the phenbic bodies considered objectionable in many oils; in optolin, these phenbs prevent the crystallization of benzene, which means that optolin may be used at low temperature; the xylol do the same thing.

Hydrogen Peroxide and Hydrazine Hydrate. The manufacture of concentrated (over 80%), stable hydrogen peroxide and of nearly some (92%) hydrazine hydrate is an outstanding wartime achievement of chemical industry.

When hydrogen peroxide is decomposed catalytrially and the resulting oxygen is discarded (as in the A-4 turbine), then the greatest advantage is not being obtained from the hydrogen peroxide. The way to use hydrogen peroxide to best advantage is to have it oxidize another substance directly. Unfortunately, it does not seem to ignite satisfactorily with such common fuels as alcohol or decalin. The great importance of hydrazine hydrate is that its use makes it possible to make the best use of hydrazin peroxide as an oxidant.

Hydrazine hydrate is not used without a catalyst; in the absence of a catalyst, ignition delays occur, and these sometimes result in explosions. The most common catalyst is potassium cupro cyanide dissolved in hydrazine hydrate or a solution of hydrazine hydrate. The reason for choosing a complex salt like K_3 cu $(CN)_4$ is that the concentration of free copper ion must be maintained infinitisimal or the hydrazine hydrate would reduce it to metallic copper, which would precipitate out. Sodium nitro proxside, Na2 Fe $(NO)(CN)_5$ is a less successful catalyst.

Hydrazine hydrate is used in the G.A.F. as explained in S;L heath's report; its use in torpedoes (along with decalin) is given in a German document "Fstuff Tagung" that will be translated.

Hydrazine hydrate was being made for 4 to 5 RM/kg; concentrated hydrazin pentide for less.

The other uses of hydrazin pentide will not be mentioned here since nothing new regarding them has come to light on this trip.

New Fuels. We have not heard of any radically new fuels. The use of metal alkyls (zinc and aluminum compounds) to ignite rockets is mentioned in enemy literature available in London. There has been mention of an interesting fuel containing suspended aluminum with which Saenger is said to have been working at Trauen in the Cumsbunger Heide. (This fact was reported by Dr. Zwisky in a previous report and confirmed by him here in an interview with dipl.Chemi Meller, formerly of Peenemunde.)

Materials in Storage At Hollriegels kreuth, there is stored 400 tons of 35% hydrogen peroxide. Since the concentrating plant is ready to operate, this material could be concentrated in about a week. Tank cars for shipment are available and the rail problem was being solved.

At Gersthofen, there is said to be 50 tons of hydrazine hydrate; some 20 tons being of the 92% grade, the rest 80%.

Steps should obviously be taken to get both these stores of materials out of Germany.

Specific Thrusts

Apparently the operational weapons worked at specific impulses considerably below the theoretical and also below the best results obtained in static thrust chambers. In the case of the A-4, although they had obtained S.I.s of the order of 217 U/co/sec, the weapon operated in an average of 207 U/Co/sec.

For the Nitric - Visol, Nitric - Optolene and acid systems, impulses 10 to 15% below the theoretical were accepted. This produced impulses of 184 U/Co/sec. Mixed acids gave slightly lower impulses. Tests using various fuels with acid were reported as only making a difference of 1 to 2% in the specific impulse.

The disparity between the theoretical and actual impulses might indicate that they tolerate incomplete reaction for the sake of the additional cooling effect the partially reacted fluids give to the surfaces of the combusted chamber and venturi.

MEMORANDUM: Interrogation of Prof. Dr. HANS BUSCH, Kitzingen, 21 April, 1945.

Dr. Busch was interrogated by F/Lt Stokes and Dr. R. W. Porter.

Dr. Busch explained that he was in charge of all negotiations with the Rustungsamt concerning transfer of personnel from Darmstadt to the services, etc. However he claims to have had nothing to do with the assignment of technical work or problems.

His own work included development of a low-frequency oscillator (1 to 50 Hz) and a Frahm-type frequency meter with a special photographic arrangement to enlarge the picture in the direction of vibration, but not in the other direction. Both of these were done for the A.E.G. Dr. Busch thinks the two problems were related and that they had something to do with the Navy. They were finished about two years ago.

The Peenemunde, Dr. Busch has developed the receiving and indicating end of the telemetering system. The transmitter was developed at Peenemunde and probably built by Firma Dr. Hell in Berlin. Twelve bits of information are transmitted five hundred times each second. In ad ition there is a thirteenth signal which is used as a standard for the gain control for the system and for synchronization. These signals are all sent as pulses or steps in the carrier and appear on the CRO as simultaneously drawn curves. At first he used only one C.R.O. tube, but later developed arrangements using two or four separate CRO tubes, with a correspondingly fewer number of curves on each tube.

He also did some work on a problem given him by Dr. Stegmaier of Peenemunde, which involved measurement of the effect of acceleration on quartz-crystal oscillators. Two crystals were used in order to eliminate the effect of temperature. Results showed 5 x $10^{-?}$ frequency accuracy whereas it was required to be only 1 x 10^{-8}. Results were purely negative. Dr. Busch does not regard this as very important.

His most recent job was a transmitter for twelve frequencies using twelve crystals and a switching arrangement. He did not know the application, but did not think it was for the Hs293. The problem came to him from Peenemunde this year and was required to be done in six to eight weeks.

The telemetering work was controlled at Peenemunde first by Dr. Muller No. 2, a former pupil of Dr. Busch and later by Dipl. Ing. Kraemer. Its code name was Messina.

The fact that this code name was the same as that used for the W/T type of Brennschluss control did not come to mind until after the interview; Dr. Busch was not asked about it. It does not seem, however, that there could be any connection. The telemetering equipment is to be built by Fernmelde u Apperatefabrik Oberspree, S.E.Berlin, in charge of Dr. Wuchel.

Incidentally Dr. Busch was Vorstand of the Arbeitsgeheimschaft Peenemunde Vorhaben, D.E.-12.

R. W. PORTER.

8 April 1945

Report of interrogation of Dr. Heymann at the Heymann Gyroworks at Bensheim, Germany.

Dr. Heymann was not interrogated in any form of progressive interrogation, due to the fact that there was quite a bit of activity present in installing lights and in investigating and searching of the various levels of his factory.

Dr. Heymann is the sole owner of this plant. He used to have a similar, above ground plant in Darmstadt, and in addition used to do most of his own work in a laboratory of his own near the main station in the same town. He was producing three types of gyroscopes, a small one of which two samples were secured, another one small and for vertical installation of which a secondhand model was secured and a third one which according to him was an old model which was declared obsolete when the German armament industry tried to normalise their gyroscopes.

Sometime in September his above ground plant was utterly destroyed an all production eased. However, the Dr. received orders from the Rustungskommando to transfer his activity to the marble mine of Dr. Link in Benzheim. This mine which has its origin in Roman days consists of a number of levels and shafts, driven into the mountain for the purpose of obtaining crushed marble, which was used in various forms, as building material, fertilizer etc.

In the beginning of the mineplant period, attempts were made to salvage whatever machinery could be salvaged from the burned plant in Darmstadt. This shop was set up in the courtyard of the old marble grinding mill. As this operation progressed, Dr. Link, the original owner of this mine prepared it for the reception of Dr. Heymann's Factory. A unit of the organization Todt furnished the labor. The first branch to move into the mountain was the salvage shop, next the small horizontal gyro production unit, then the vertical gyro repair unit.

According to Dr. Heymann, the factory in Darmstadt had produced approx. 3000 units per month, in December the production inside the mountain amounted to 150 units monthly and at the time of our troops invasion of the mine the production figure was up to 1500 units. It had been hoped that in three more weeks the plant would produce the equivalent of the original Darmstadt factory.

Apparently Dr. Heymann would not tell or did not know where the units were ultimately used. He claims that the "Fuhrer", from the Bezirksrustungskommando would allocate the specific production of parts to the most likely manufacturer and he would know the overall set up, as far as assembly and destination were concerned.

Unfortunately, due to the limited personnel on hand for the job not many details could be ascertained during this investigation of the plant. Another drawback was the fact that the Dr. had, under orders from the Rustungskommando, destroyed all secret and confidential matters and correspondence. Then his main production man, a young Mr. Eupel, who perhaps is the key man to this whole set up was not at the plant or available. This man, from correspondence found made frequent trips to Berlin and surely was a Nazi and knew more of the whole work and its position in the industry than can be obtained from any interrogation of Dr. Heymann.

ome minor items found worth mentioning are: The mine is in danger of drowning slowly.

The lower Sohle or level, which contained some experimental machinery was found to be well under water. The pump, which was originally installed for the purpose of saving the mine ran on 380 volts, which voltage was not obtainable with the machinery at the disposition of the U.S. engineers which are now supplying the mine with light and possible power.

When Dr. Heymann was ordered to cripple the factory, (not to destroy it!) he had asked for sufficient grease to preserve the large amount of machinery, of German and Swiss manufacture. But grease was unavailable and so the machinery is, due to the humidity of the mine, in progressive stages of rusting. On a rough estimate this machinery presents an investiment of approximately 60,000$ and is of secondary quality at that.

A second shaft to the outside was contemplated and found by our military police. From the general aspect of this project undertaken by the Germans to rehabilitate the destroyed industry it seems very probable that the mountain range here and farther to the South contains a great amount of these smaller factories. The investigation of all presently worked and formerly abandoned mines in this area will in all probability yield more discoveries of this kind.

MEMORANDUM: Interrogation of Dr. Ing. HANS HYMAN, Kitzingen, 22 April, 1945.

Dr. Ing. Hyman was interrogated by Dr. Porter and F/Lt Stokes:

He claims to be an expert in producing all kinds of oscillations and vibrations, and correspondingly in the measurement and removal of vibration. In particular he belives that he has developed the science of "symptomatic analysis" of troubles in rotating machines to a high degress.

Early training of Dr. Hyman was at Karl Schenck, GmbH, at Darmstadt, Landwehrstrasse. This firm was engaged in the design and construction of "Wuchtmachine" or dynamic balancing machines.

He eventually left Schenck because of some personal difficulties between himself and the owner, and started in business for himself. About 1940 his work began to be recognized by the various military establishments and he was called on by the R.L.M. to develop methods of testing all sorts of gyroscopic devices for aircraft. His particular claim is that he developed instruments which (a) allowed the gyroscopes to be tested in the devices in which they are used, i.e. in their mountings, and (b) that he reduced the testing procedure from one requiring two to six hours by an expert to one requiring only about fifteen minutes by a girl. He describes his methods as being comparable with the electrocariograph idea in medicine; in fact he says that the idea was first put in his mind by a discussion with a physician during treatment for heart trouble, from which he has suffered for a long time. As nearly as could be determined in this short interview, the method consists of a pick-up device of some sort, an amplifier, and a cathode ray oscillograph together with the technique required to analyze the resulting trace and determine the source of the vibration.

His reputation in this work was such that he was asked to manufacture gyroscopes, which he did at Darmstadt. When this establishment was bombed out, he moved to an underground location at Auerbach, Bergstrasse, near Bensheim. His maximum monthly production reached 3500 per month at Darmstadt, but had not got underway to any great extent at the underground plant at the time it was occupied.

Other companies with which he worked on gyroscope problems were Kreiselgerate GmbH, Berlin, Firma Horn in Plauen, and Firma Ohnig in Hartla near Schemnitz.

His orders for gyroscopes came from the Rustungsstab, Berlin from a Herr von Wedelstadt. This organization gave him half a million RM to expand his facilities and to set up the underground factory after he was bombed out at Darmstadt.

In addition to his work on gyro problems, Dr. Hymann has carried out experiments in the compression of powdered materials by means of vibration, separation of materials according to size and density on a vibrating table, and detonation of mines by vibration.

The compression experiments seem to have been rather extensive and apparently more successful. For example, Dr. Hymann claims to have reduced the volume of flour and other powdered food-stuff to less than thirty per cent of the original volume. Powdered explosives called Hexogen and Gelbpulver furnished by D.A.G. were compressed to a density essentially the same as that of the homogeneous material. Metal powder was pressed into bullets, etc. These results are obtained, he claims by the superposition of vibrations of different frequency in at least two axes simultanously. The exact values of the various frequencies and their magnitude depend on the size, density, and hardness of the grains. For some kinds of work supersonic vibrations are used.

Lack of time unfortunately prevented obtaining more detailed information from this subject. He was asked to draw a sketch showing the location of his various establishments. This sketch is attached. It shows five different units, one of which was the gyro manufacturing unit at Darmstadt, one of the underground establishments at Auerbach which replaced the first when it was bombed out, (designated as 1 on sketch) a unit in Darmstadt later moved to Hallein (?) designated as 2 on the sketch, one at Nieder Ramstadtbei Darmstadt (designated as 4 on the sketch) and one at Parquai (?) (designated as 3 on his sketch). The unit at Nieder Ramstadt is the place where samples of powder pressings may possibly be found, and the one at Parquai (?) is the one in which work on mine detonators was being carried out.

Units listed as 1 and 2 on his sketch were incorporated under the name, Dr. Ing. Hans Hyman, Forschungs u Produktion Messtechnik, whereas those designated as 3 and 4 went by the name, Dr. Ing. Hyman & Co. Forschungs Institut.

R. W. PORTER

CIOS FIELD TEAM ASSESSMENT REPORT

1. TARGET NO. Target of Opportunity.

2. TITLE OF TARGET. Dr. Ing. HANS HEYMANN

3. LOCATION, BENSHEIM, Germany.

4. CONDITION OF TARGET, OPERATING CONDITION (See attached report)

5. DESCRIPTION OF ... Small second quality lathes, drill presses and planers. a full inventory is available from the 54th Disarmament Squadron, which includes very complete assortment of gyro rotor parts, motors and testing equipment for balancing the gyros. The gyros were of the 110 volt a.c. 500 cycle type which operated at an rpm of 2[illegible],500. Samples of the gyro were obtained and documents explaining the method used for dynamically the gyros are being furnished to R.A.E. Farnborough and Wright Field for further study.

6. ITEMS GUARDED:

a. Equipment) Guarded by the AMG of Bensheim at the time of this report.
b. Documents)
c. Personnel)

7. PRIORITY ASSESSMENT # 2

8. OTHER REMARKS: See attached report of interrogation of Dr. Heymann.

9. DATE OF ASSESSMENT: 8 April 1945.

10. ASSESSORS NAMES: Flight Lt. Cedric Goldie.
Major W. W. Harkinson. AC.

Army Group - 6th Army Group
Item Group - CIOS Team # 4

DISTRIBUTION: CAFT
T Force Commander
File.

Preliminary Report of A Target of Opportunity

TARGET: Rocket Motor Test Station of Bayerische Motor Werke (BMW)
LOCATION: Allach near Munich
VISITED BY: Lt. Col. G.J.Gollin, S/L E.J.Kenny, Lt. Ozol, H.A.Liebhafsky
(British) (British) (U!S!Ord) (Civ.Tec.)

This target has been assessed by a CAFT team, and Squadron Leader Robinson(British) (CAFT) informed us that a C.I.O.S. team to investigate it has been requested. He did not object to a preliminary investigation by the above mentioned members of the C.I.O.S.
Team No. 183, who stopped here en route to Garmisch-Partenkirchen.

There is no doubt that the target is one of the outstanding German stations for stationary tests on rocket motors. Stations of comparable importance seem to have been only at Peenemünde and Berlin. For this reason, it is of interest to compare it even briefly with the Ordcit Station at Pasadena and will the plans at Schenectady.

We were conducted through the station by Dr. Hemesath, chief chemist of BMW for rocket fuels, who claims (along with others-see my earlier reports) to be the inventor of hypergole fuels utilizing nitric acid as oxidant. He claims furthur that some 6000 rocket -fuel combinations have been tested at the target. Nitric acid was the only oxidant used in these tests; many reducing agents (fuels) were tried, the choice of these being dictated largly by supply considerations. Hydrogen peroxide has been studied for submarine purposes in the laboratory, but never in a rocket motor.

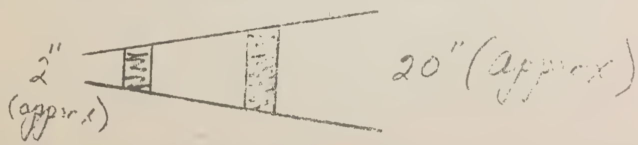
The station was begun early in 1943. It was to consist of 12 pairs of test pits, each pair having one control room. Most of these pits were built, but not all were operated, Thrust was measured hydraulically through a membrane. There was also an electrical method of thrust measurement, but this did not involve a quartz crystal, a reasonable guess is that it involved changing the capacity of a condenser by a mechanical displacement proportional to the thrust. (The CIOS team expects to clear up this matter and to obtain samples of the thrust-measureing devices) The reactants are delivered by pressurizing, air or nitrogen being used. Reaction is begun by having an explosive rupture a metal membrane; this starts the flow of reactants (Lt. Col. Gollin says that he is throughly familiar with this method which he uses) The hypergoles are self-igniting;for the other fuels, ignition by means of gunpowder, by means of an electric spark, n[illegible] by means of hypergoles in small quantit[illegible] has been used.

Two features of this station are particularly interesting. One is the central storage system for the reactants. The fuels are kept in large tanks centrally located (they seem to be made of steel); the nitric acid is kept in a large aluminimum drum. The tank can be weighed before and after an experiment to give the fuel consumed. Pipes lead from these tanks to the various test pits. This central fuel system had actually never been used because there had not been time to complete it.

The second feature is the means of getting rid of the exhaust gases. Each test pit exhausts into a replaceable sheet iron circular duct about 3' or 4' in diameter, which is located in an enclosure behind the test pit. The opening of the duct may be 10 or 15' from the motor. The duct leads into a square brick duct, 5 or 6' on the side which has a stack may be 45' high at one end. Ducts not in use may be closed. Attached tothe stack is a blower, which sends air up through it. This moving current of air is made to carry the gases out of the stack. (It is hoped that the final CIOS report will include plans of this gas exhaust system)

The excellent lighting of the test pits is noteworthy. The glass protecting the lights has been cracked by flying pieces of motors.

One man has been killed or seriously h[illegible]t in experiments at Allach. Nevertheless, their safety precautions seem to be well taken, and there have been no injuries of operators who followed instructions. The walls of the test pits are reinforced concrete about 30 inches thick. The peep holes are arranged as shown below in sections



The shaded sections are safety glass built for submarines. Each section is about 4" thick. The space between the sections can be heated electrically or a dyhydrating agent can be introduced into it. During a run , awire netting is lowered to protect the glass from pieces of an exploding motor. Such explosives are not uncommon because nitric acid tends to form explosive organic nitrates if the oxidation of the fuel does not proceed rapidly on mixing.

Needless to say, Dr. Hemesath feels that nitric acid is the most promising of all oxidants for rocket purposes. He admits, however, that no operational use has yet been made of it in Germany, but says that there have been trial flights. Most experiments were done with 5.1 ratio of nitric acid to fuel, which means the nitric acid is in excess Only fuel and acid rates and thrust were measured.

Most experiments have been made on motors like that for the X-4, where the mass ejected per second is near 0.8 kilograms; duration of the experiments was usually about 20 seconds. Work has also been done on assisted take-off units for rocket planes;these experiments were on a 10 fold larger scale and were longer continued. Specific impulses around 200 seconds seem to have been reached; this point requires checking.

H. A. Liebhafsky
T/O U.S. Ordnance,
Munich, Germany,
May 12, 1945.

THE STORY OF PEENEMUNDE

PART II

THE AERO-DYNAMIC-BALLISTICS RESEARCH STATION, KOCHELSEE.

(Sec. 1) Description of equipment etc.

Lt. Col. J. A. O'Mara	USSTAF (Team Leader)
Lt. Col. G. J. Gollin	Br. M. of S.
Major J. Iball	Br. M. of S.
S/Ldr. E. G. A. Kennig	Br. A.I. (2) G.
S/Ldr. B. A. Sharpe	Br. M.A.P.
F/Lt. H. R. Stokes	Br. A.D.I. (k)
Dr. R. W. Porter	U.S. Ord.
Dr. H. A. Leibhafsky	U. S. Ord.
Dr. Fritz Zwicky	USSTAF

CIOS Team No. 183.

SECRET

OUTLINE OF CONTENTS

SECTION A **Page No.**

Description of the whole equipment, organization and some details concerning the most interesting and important methods.

3. Additional Notes.

SECTION III

Basic Researches of Gasdynamics, aerodynamics and thermodynamics.

SECTION I

Description of the whole equipment organisation and some details concerning the most interesting and important methods.

I. Introduction - The Hydraulics Experimental Station, Kochelsee (WVA)

Camouflage name for

Aero-Dynamic-Ballistics Research Station, Kochelsee

Director and Chief Engineer:

Prof. Dr. Phil. Habil. Rudolph Hermann

Assistant Directors:

Dr. Phil. Hermann Kurzweg
(for Science & Research)

Dr. Phil. Herbert Graf
(for Commercial Operations)

Business Manager:

Dr. Engr. Gerhard Eber.

A. Field of problems of the Hydraulic Experimental Station, Kochelsee.

The Hydraulics experimental Institution Kochelsee is an aero-dynamic-ballistics experimental Institution which, for reasons of secrecy, has received the name of Hydraulics Experimental Station.

a. Scientific Problems:

Theoretical and experimental research of compressible streaming processes with the center of gravity in supersonic current, particularly at high math. figures. For instance: Currents through Laval nozzles, return gain of pressure in diffusers, current flow around a wedge, cone, ball, cylinder, current flow along plates around profiles. Analysis on extremity or boundary layers, analysis on turbulence, development of mensuration, methods for electricity, optics, thermodynamics, accoustics.

b. Research problems for technical developments:

During the time from 1939-1945 the activities consisted of work on the following war problems (or contracts):

1. The gaining of results through aero-dynamic research to be used as a basis for the construction of the great distance rocket A4 and the experimental rockets A-3 and A-5, development of such to be at Peenemunde.

2. Further development of the device A-4 for greater firing ranges. (A-9 also called A-4b).

3. Preparation of the aero-dynamic and outer-ballistic foundations for:

(a) Entire development of projectiles and shells for the Ordnance Division, War Department. Form or shape giving for projectiles for field artillery. Long range artillery, anti-tank, fog or smoke screens.

(b) The aero-dynamic form given projectiles for flak-artillery, rocket projectiles for arms (mounted on aircraft) for instance "Drachen" (Dragon); controlled and uncontrolled flak-rockets from the ground to the plane, especially; Wasserfall (WATERFALL), Taifun (Typhoon), Rheintochter (Rhine-daughter).

(c) The armament industry: Krupp, Roechling, Rheinmetall, Skoda, Magg, Bochumer-Verin (Bothum Association) Wittkowitz.

4. Besides the above-named aero-dynamic problems, the

constructive development of the so-called Peenemunde-Arrow-Projectiles (PP G) was undertaken and carried out after their own Aero-dynamic and constructive points of view.

c. Planning and construction of the "Superschall-Windkanals (Supersonic wind channel (tunnel) 57000 KW.

Cross-section 1m x 1m, continuous operation, Ma=7, developing up to Ma = 10; to gain the Aero-dynamic foundations for long distance rockets for ranges of several thousand kilometers for the commerce between the continents.

B. Chronological Survey of the development of the WVA and its predecessors at Aachen & Peenemunde.

1934-35	Construction of the first supersonic wind tunnel by Dr. Hermann, Professor at the Aero-dynamic Institute of the Technical High School, Aachen. Principal Professor Wieselberger. (Cross section 10cm x 10 cm, Ma = 3).
1936-37	Carrying out the first measurements for rocket projectile A-3 (first step for A-4). Building of a second supersonic wind channel at Aachen, cross section 20cm x 20cm.
1936-37	Layout and drafting of the 40cm x 40cm supersonic wind tunnel on order of the ordnance (War Department) by Dr. Hermann for the experimental station, Peenemunde.
1937	Founding of the Aero-Dynamic Institute at the experimental station Peenemunde. Principal Dr. Hermann. 16 Co-workers. Construction of the channel. Cross section 40cm x 40cm, blowing time 20 seconds, capacity 810 KW.
1939	Setting into operation of the wind channel with 1 measuring range, approximately 60 co-workers. Execution of 3-component mensurations.
Till 1943	Steady enlarging of the Institute due to increase in orders, expansion of the experimental plant, erection of new laboratories and increasing the number of co-workers. Speed up to Ma = 4,4 (correspondingly 1450 m sec).
Aug.1943	5 measuring ranges, approximately 200 co-workers. No destruction of the Institute suffered from air attack on Peenemunde.
End of 1943	Beginning construction on the supersonic wind tunnel at Kochel/Obb. which was drafted in 1942.
Jan.1944	Founding of the Hydraulic Experimental Institute Kochelsee G.m.b.H. by Dr. R. Hermann and Dr. Herbert Graf for the purpose of designing, building and distributing stream or current-technical devices.

Severing of the Institution from the Experimental station Peenemunde and moving same to Kochel.

Oct. 1944 Completion of the plant in the rough and putting into operation on measuring range of 40cm x 40cm, up to Max 4,4.

C, Division and work distribution of the WVA.

The hydraulic experimental institution is divided into departments, main groups and groups, which in their sizes and personnel strength are capable of solving the particular problems of the various fields, namely, the theoretical and experimental research, execution of the experiments, maintenance and improvements on the technical plant and installations, as well as general operation and commercial administration.

This organisation plan was not adhered to too rigidly but was left flexible to the extent of readily adapting itself to the changes and needs required by the temporary shelving of one project and the moving up to priority of another. The following statements may serve as an illustration of the special kinds of work carried out.

a, Department Experimental Laboratory:

Dr. Phil. Hermann Kurzweg - Working out of all questions and problems of aero-dynamics, mathematics, thermo-dynamics and related fields, theory, as well as experimental testing of models.

Dr. Phil. R. Lehnerta - Main Group - Aero-dynamic mensurations. Theoretical and experimental analysis of the development of aero-dynamically favorable forms and shapes for fast flying bodies of their own and foreign designs.

Dipl. Engr. Max Raffel:

Group 1: Three-component mensurations. Mensurations to gain knowledge on resistance buoyancy, and body momentum.

Group 2: Miscellaneous mensurations. Mensurations to ascertain stability and dirigibility.

Group 3: Photo Department. Photographing and filming of experimental research in all departments, main groups.

Dr. Peter Wegener (b) Main Group - Aero-Dynamics basics research. Theoretical calculation and experimental rechecking (proofing of aero-dynamic characteristics of newly developed bodies, wings, guiding gear and rudders of their own and foreign ideas.

Dipl. Engr. Hans Ullrich Eckert - Group 1: Dynamic Experiments. Experiments by dynamic methods, on swinging or oscillating models to find the basis for stability, capability of support, wave or better stability and dirigibility.

Group 2: Statistic Experiments - Experiments for finding the distribution of pressure on body, wing, guiding gear and rudder on a rigidly held model.

Dr. Phil. Willi Heybey - C Main Group: Mathematics bureau. Evaluation of the mensuration results, transfiguring the results of the model experiments to actuality of free-flight.

Std. Ass. Feodor Schubert - Group 2: Theoretical gas dynamics. Research and calculation of the methematic-theoretical basis of current processes in super-sound and compressible sub-sound.

Can. Math. W. Zettler-Seidel - Group 3: Calculation of Trajectories. - Application of the theoretic and experimental knowledge gained, on outer ballistics. Developing of systems for the calculation of the actual flight course in free-flight.

Dr. Phil. Wener Kraus - D Group: Thermodynamics. Theoretical calculation and experimental analysis to gain knowledge on the heating up, the heat transformation and its influence upon the aero-dynamic and constructive qualities of flying bodies. Development of temperature measuring methods on currents of supersonic speed.

Dr. Phil. Ernst-Hans Winkler - E. Group: Optics. Developing and improving on optical devices and instruments, necessary for the experimental analysis. Especially on equipment used in streak optics, the interferometer for qualitative and quantitative mensuration of current processes.

Dipl. Engr. Siegfried Hoh - A Main Group: Electro mensuration.

Developing of electric measuring methods for the mensuration of current processes.

Dipl. Engr. Gottfried Arnold - Group 1: Physical measuring methods. Application of X-rays for measuring the density (pressures) of current processes. Analysis on expansion of sound waves in super sound with electric measuring devices.

Group 2: General measuring methods. Development of electrical systems of the three-component scales to measure the forces on a model during the wind tunnel test. Development and application of electric pressure gauges used in ascertaining pressure distribution.

Dipl. Engr. Max Peucker - B Main Group: Electro-operation. Planning, extension and superintending the electrical end of the experimental plant and machinery of the Hydro-experimental station.

Dipl. Eng. Josef Cerny: Group 1: Planning and Construction - Erection of switchboards and construction and improvement of machines and control apparatus of the wind tunnel.

Group 2: Operational Supervision - Servicing and supervising of machines and control apparatus during operation tests.

Group 3: Construction of Equipment. Development and construction of electrical measuring apparatus and circuits for the wind tunnels and their operational observation.

C Department of Technical Development:

Chief Eng. Hans Gessner - Constructive development of the wind tunnel installations and preparation of foundations. Construction of models and mechanical parts of the measuring apparatus. Construction of arrow projectiles as a result of new aerodynamics discovered and the preparations of completion plans for the armament industry. Construction of models and important parts of the wind tunnel in the workshops.

(a) Ing. Josef Kuckertz:

(a) Main Group: Construction:

Completion of calculations and preparation of the construction drawings.

Group 1; Mensuration range.
" 2: Arrow projectiles.
" 3: Models.

Eng. Edmund Stellenmerk - B Main Group: Fabrication. Machine and precision shops.

1. Supervision bureau - Shop direction and administration.
2. Job preparation.
3. Workshop - Machine fitting Department, lathe department, milling machine dept., planer dept., cabinet-making, precision department, tool crib and stock room.

d. Department Wind Tunnel - South (WS) Dr. Engr. Gerhard Eber.

Problems: Designing and constructing a wind tunnel with a hydro power station between Walchensee and Kochelsee of 1m x 1m cross section for 7 fold speed of sound (Aim of development: 10-fold speed of sound) with and installed output of 57000 KW. The project was carried out by the Hydro research institution in collaboration with the material supply firms. The hydraulic end of the plant project was worked out by government building engineer Schlegel of Munich.

Dr. Phil. Karl Heinrich Gruenewald - A Main Group: Scientific questions. Clearing (explaining) of all physical and technical questions arising during the building of the wind tunnel for instance, in regards to air drying, behaviour of the air during the expansion in the Laval nozzles.

Dipl. Engr. Guenther Dellmeier - B Main Group: Mensuration range. Contraction of the mensuration range with inflow-funnel, mensuration chamber, diffuser three-component scales, and Schlieren optics. Erection of the mensuration range in collaboration with the firm of Dingler, Zweibrucken.

Dipl. Engr. Albert Haller - C Group. Machinery plant. Calculating and designing of the turbine unit, consisting of 4 twin Freistrahl (free stream turbines) of output, each 12000 kW directly coupled with vacuum pumps and 3 single stage free stream turbines of 3000 kW output each for the generation of electric energy in co-operation with the firm of Veith, Heidenheim.

Calculating and designing of the vacuum pump assembly, consisting of 7 blower stages with one suction line of 1200000 m^3/H. to produce a vacuum of 1.4mm QS (Mercury Column?) including the appropriate cooler and switching apparatus and auxiliary machines in cooperation with the firm of Brown Boveri and Co. Mannheim.

Designing of the air-drying installation for the drying of approximately 870,000 kg of air per h. from of 12g/kg moisture to less than 0.5g/kg through the medium of silicic acid-Gel in collaboration with the firm of Silca-Gel-Gesellschaft, Berlin.

Dipl. Engr. W. Schlesinger - D Main Group: Electric Installations. Developing all electrical equipment necessary for the operation of the installation, such equipment as was chosen on ground of experiments made in research on the existing wind tunnels.

e. Main Group: General devices and installations, fabricating and procuring laboratory equipment, measuring instruments etc. necessary in the operation of the wind tunnel. Fitting up of several laboratories in conformity with latest standard methods.

Data on the Building Construction:

Beginning of the building November 1943, time provided for the building - 2 years. Operation of the installation in its first stage should have begun in Autumn 1945. Work on the building project ceased in March 1944. The geological analysis and surveying works of the hydraulics part have been concluded. Building of the machinery installations carried on until September 1944. Detailed parts of the installation (such as driving gears, and blowers) are at Kochel.

f. Department Administration: Dr. Phil Herbert Graf.

Handling of all operational and commercial administrative questions were normally dealt with by an association of limited bomb (guaranty) Details along these lines are taken for granted and do not need any special mentioning in the organisation plan.

g. Assistant of the Management - Engr. Guenther Herrmann.

D. Power Installation.

The WVA at Kochel takes its power from the Walchensee power plant, which is the largest hydroelectric plant in Germany with a peak capacity of 168,000 H.P. It is undamaged. The power demands of WVA are only about 2% of the plant's normal load.

At the present time, WVA is served by two transformers at the power plant; the larger of these, 6000 kVA, 106050/1900 volts is on loan from Rhein-Main-Donau, Munchen, and may be recalled at any time. The second transformer, which steps the 1900 volts up to 6000 volts, had to be used because the first was not adapted to this job; this second transformer is overloaded when WVA is at full capacity. A transformer to replace these two, 5500 KVA, 106000/6000 volts has been ordered from and made by OTE (Italy); it is presumed to be in Bozen (Bozano)

The wind tunnel pumps are operated on 6000 volts; the lighting, drying installation, and similar circuits operated on 380/220 volts.

2. General Remarks on the Equipment.

A. The drying of Air for the Wind Tunnels.

In the present intermittent wind tunnel, air is admitted through a semi-cylindrical section containing 7 tons of silica gel. The drying system is described in the HVP report Archiv Nr. 66/49 by Dr. Grunewald. Certain information not given in the report is given below.

The air passes through the drying section at a velocity near 1 m/sec; the section has a surface of about 30 sq. m. and gel section is 30 cm thick. Reactivation is by means of a cold blast of dry air, this is necessary because the time between the 20 sec. runs is only 3 to 5 min., which is not long enough for a reactivation by heat. A reactivation follows every run. The blast of cold dry air is generated in an installation comprising two absorbers, of which one is reactivated by heat while the other is in service, heaters and coolers. In general, the water content of the air delivered was about 0.1 to 0.2 g/kg; in very humid weather it was worse. The present charge of silica gel has been in use 5 years; the only deterioration observed has been a gradual pulverisation; the powder settles to the bottom of the section and increases the resistance to flow.

The drying installation planned for the continuously operating wind tunnel will be different. The semi-cylindrical section will be replaced by two plane drying sections, which may be shut off from each other to permit separate reactivation. (The semi-cylindrical shape was originally adopted to give radial flow, but this was found unnecessary). The throughput will be 400 cu.m./min. of air, the dryness expected being about that now attained. A wind tunnel run will last ½ hr; reactivation of the silica gel is expected to require 3 hours.

(Additional Notes).

1. The drying system is interlocked with the "Schnellschlussventil" in such a way that the stream of dry air from the former escapes through a by-ass when this valve is open, but goes through the silica gel to reactivate it when the valve is closed at the end of a run. This scheme must of course be modified when a "hot activation" of the silica gel becomes necessary, as it does once a day under the worst conditions. Such activation requires about 3 hours and may be necessary only every 2 weeks in winter.

2. Changes involving the model being studied are made during the period required for the reactivation of the gel and the pumping-out of the reservoir (750 cu.m. capacity; another reservoir of 1000 cu.m. is being built).

3. Safety measures are taken to make the entire installation fool-proof; usually these are at least two safety measures to protect against a given hazard. In the pumping installation, the switches cannot be

closed or remain closed if the cooling water is not running through the pumps; if the air being pumped rises over 280°C., the pumps stop; if the pressure in the line increases above 3 atm., the pumps stop likewise; there are also bursting membranes to guard against the same contingency. Similar precautions are taken on the wind tunnel itself.

4. The great hazard in the operation of the tunnel is the danger from flying glass when the glass walls of the chamber fail. So far no one has been injured in the operation of the tunnel, either here or at Peenemunde.

5. To start the tunnel, a foot switch must be pressed twice, once to divert the stream of dry air into the by-ass and again to open the "Schnellschlussventil". This makes certain that the dry air is being by-passed before operation can begin.

6. A good fit of the "Schnellschlussventil" is very important to prevent losses due to the generation of shock waves; these could be serious enough to prevent the obtaining of supersonic flow.

7. Different Mach numbers are obtained by changing the nozzle in the wind tunnel. Three men can make such a change in 13 minutes.

8. The pumps are rotary air compressors containing movable blades in an eccentric housing. The blades are held against the housing by centrifugal force when the pumps are in operation. The compression ratio, which may have values ranging up to 10, depends upon the design and upon the leakage past the blades.

B. Operation of the Wind Tunnel.

The following steps are taken in order to resume operation after a normal shut down:

1. Close circuit breakers for the pumps and the drying installation (3 minutes).

2. Start the cooling water flowing through the pumps. Start the pumps. (3 minutes).

3. Start the cooling water in the drying installation. Press button to start the installation. (2 minutes).

4. Insert model into wind tunnel. This operation requires 5 5 minutes in the simplest case when only lift, drag, and pitch are to be measured. The mounting of models may require several hours when pressure distribution is to be studied; in this case, both the inner and outer glass walls on one side must be replaced by steel; and this requires the use of a crane; the manometers must be connected (there may be a hundred of these). Several

hours are also required when X-ray measurements are to be made; here the steel plates must be used also. When Schlieren photographs are taken, glass walls are used; here most of the time required goes into setting up the optical system. The same thing applies to the interferometer, with which special glass sides must be inserted into the tunnel.

5. When lift, drag and pitch are to be measured, the electromagnetic circuits must be closed about 10 minutes before a run so that steady state conditions (temperature mainly) are reached. For very precise work it is desirable to calibrate the balances precisely each day, which requires about an hour; for less precise work, only two or three points need be checked. When the new balance system has been introduced, there will be no need for frequent calibration since a linear relationship will obtain between the forces and currents recorded.

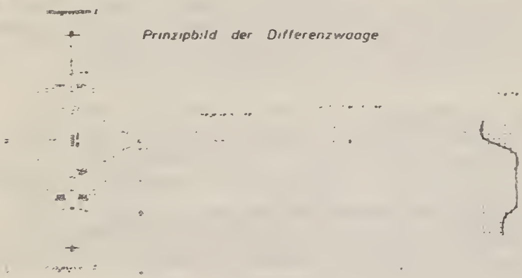
6. The 20-second run has now begun. 10 or 15 seconds suffice for the measurement of the forces. (The forces on the model and holder are usually measured first; the subsequent measurement on the holder alone requires, of course, a separate run). Pressure distribution measurements may require up to 40 people with the present system; when the electromagnetic recording pressure guage system has been introduced, all the pressure readings will be fully automatic

7. At the end of the run, the "Schnellschlussventil" is closed so that the pressure in the reservoir drops to the desired initial value for the next run. (The pumps are kept in continuous operation). The permissible initial pressure varies inversely with the Mach number of the next experiment; for example, 1.2 Ma requires "60% evacuation", so that the initial pressure is 40% of 760 mm, 3.1 Ma requires 95% evacuation; 99.5% evacuation has been attained. The pumping times required vary from 3 to 10 minutes; At Mach numbers below 2.5, the three pairs of pumps (capacity of each pair, about 200 cu.m/min.) are used in parallel, at higher Mach numbers the third pair of pumps is in series with the other two pairs in parallel; the change from one pump hook-up to another can be made by pressing a button.

6. The Balance for the Wind Tunnel.

The balances for measuring the three components (lift, drag and pitch) are shown in the attached sketch.

The distortion of the springs is read electromagnetically; a recording apparatus is complete but has not yet been installed. The complete wiring diagram is shown below:



At the present time, the apparatus in use is practically that to the left of the linear amplifier (Regelverstärker). This apparatus is now connected to an AC milliammeter, which has the disadvantage that the spring must be very stronly distorted to give an appreciable current. For this reason, the current and weight relationship is not linear. The new arrangement will be, not only automatic, but linear because the movement of the spring will be sufficiently restricted, and because both amplifier and rectifier (Gleichrichterbrücke) have linear characteristics.

The usual variations in room temperature do not affect the results. Measurements over the range 10 g to 4 kg will be made to ± 2 g (approx) without changing the balance. By changing the air gap, this range will be displaced to higher or lower values.

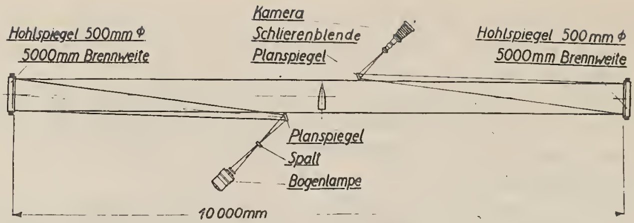
These conditions will obtain when the complete electrical system is installed; laboratory tests to show this have been made, the apparatus is ready to install.

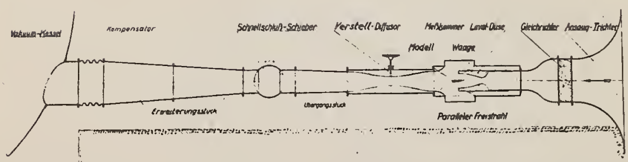
The present arrangement has the drawback that the difference required to establish pitch is obtained by the subtraction of two large quantities. A "Differenz waage" was accordingly constructed so that this difference could be measured directly over a range restricted to ensure high precision. This new balance has not yet been installed; it has been constructed and tested.

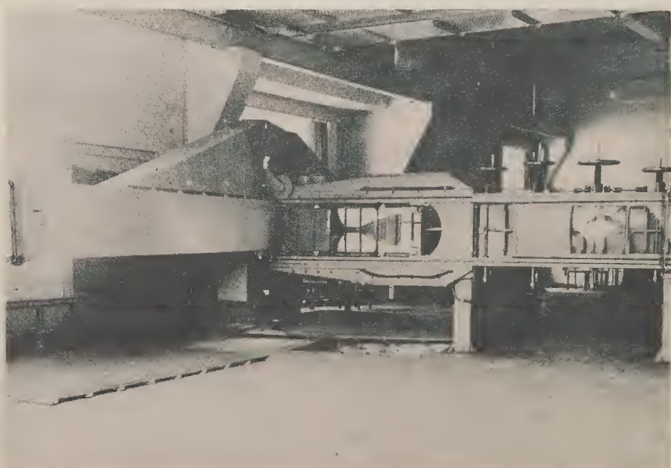
The bridge for the new "difference balance" will have two inductances for each of the two springs concerned in the pitch measurement, as shown in the wiring diagram.

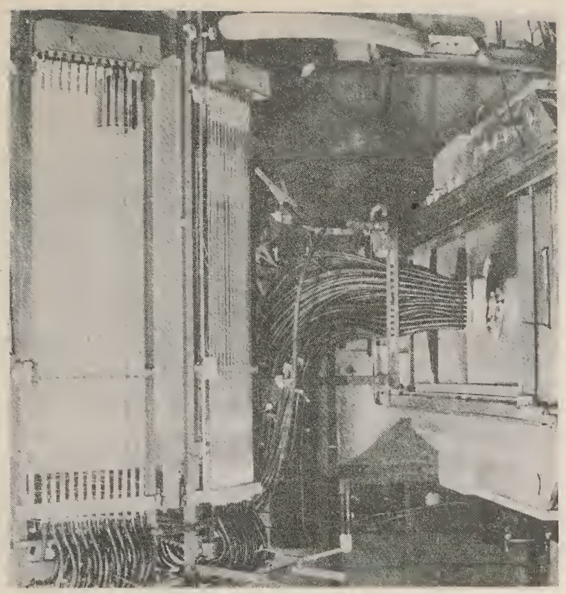
In the present bridge, two inductances are compared with two standard resistances. The "Differenz-waage" is described in WVA Archiv Nr. 66/158.

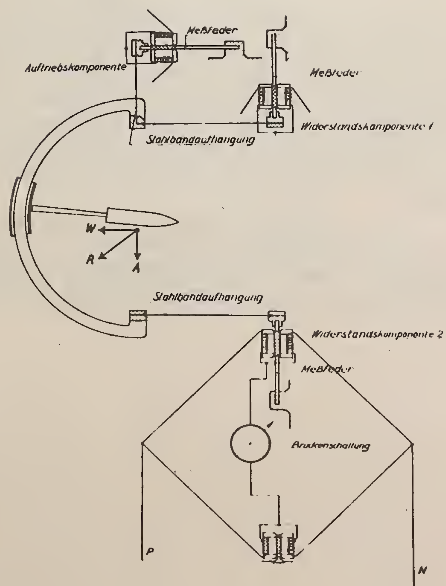
The balances are calibrated statically with weights.

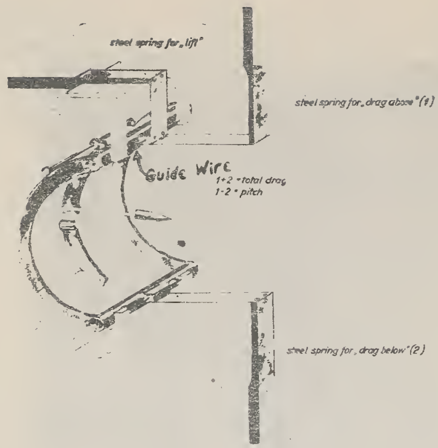

Kamera
Schlierenblende
Planspiegel
Hohlspiegel 500mm Φ
5000mm Brennweite
Hohlspiegel 500mm Φ
5000mm Brennweite
Planspiegel
Spalt
Bogenlampe
10 000mm


Vakuum-Kessel
Kompensator
Schnellschluß-Schieber
Verstell-Diffusor
Meßkammer
Laval-Düse
Gleichrichter
Ansaug-Trichter
Modell
Waage
Paralleler Freistrahl






Meßfeder
Auftriebskomponente
Meßfeder
Widerstandskomponente 1
Stahlbandaufhangung
W
R
A
Stahlbandaufhangung
Widerstandskomponente 2
Meßfeder
Brückenschaltung
P
N



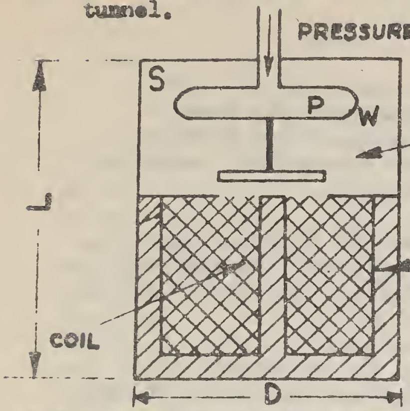
Mounting of Model and Springs for the balance.
(Note the four horizonal guide wires for the springs).

Balances within Wind Tunnel Models.

The external balance system has the disadvantage that the force acting on the model must be obtained as the difference of the forces on holder and model, and on the holder alone. If this difference is small, as in the case of a good aerodynamic body, it is liable to be inaccurate. This inaccuracy is mitigated by placing a balance inside the model, the balance being attached to the holder.

These balances are identical in principle with the electromagnetic pressure gauges; here the membranes are replaced by springs. The balances are made in a wide range of sizes.

D. Pressure indicators for small pressure in the supersonic wind tunnel.



Full range for instance 5 mm Hg with an accuracy of 1% AC in the coil ν = 1000 Herz. Errors given through mechanical hysteresis losses. Dimensions are of the order D = 15 mm L = 20 mm so they can be incorporated into the models in the wind tunnel. Space S is evacuated to a pressure at least about one hundred times smaller than the pressure one is to measure. The chamber walls on rapid evacuation must therefore be able to withstand shocks of 1 atm.

To a pressure difference of 5 mm Hg corresponds a displacement of ten microns. (= 100 divisions on the scale). One scale division corresponds to 10^{-5} mm Hg.

Ultrasound waves of about $\lambda \sim$ 1 mm to 4 mm (ν = 330 000 Hz to 80 000 Hz). Were worked upon in order to fill the whole cross section with waves, the refraction (Schlieren) survey of which would have allowed to determine the distribution in the temperature field. (Determination of the local were length of the superposed waves of small amplitude with the "Schlieren" method).

Project on the "Superschall" Wind Tunnel.

"Superschall", Mach number M $>$ 4, to "Uberschall" of Mach number $<$ 4. Neberschall flow is relatively easily attainable.

E. Optical Apparatus at Kochel.

The most interesting piece of optical equipment is a new interferometer made by Carl Zeiss. This equipment has never been used on a wind tunnel as it was only being fitted up when Kochel was captured. The apparatus had been dismantled, buried in the ground and is now in a working condition.

The interferometer is of the "Mach-Zehnder" type (4 plate interferometer). The field of view is 9 to 10 cm. The size of the channel which fits around the wind tunnel is as shown on the plan.

A plan of the instrument is attached. For adjustment there are two instruments similar to theodolites which enable one to get an exactly horizontal beam of light through the interferometer. One of them (K) is fitted in the place of the arc lamp and filter, condenser and water cell removed. The other instrument (F) is fitted on a small optical bench near plate III (see plan) and the viewing condenser removed. K_2 contains a cross-wire which can be viewed by the telescope F - Plate IV is adjusted so that the cross wire of K coincides with cross wire F. Plate IV is then at 45° to the horizontal. The other mirrors are then adjusted so that all four are parallel. Plates I + III are semitransparent mirrors the back surfaces of which are made non-reflecting. The final adjustments must be made with the arc lamp and monochromatic light. The zero setting is made by using white light and moving the plate III parallel to the horizontal beam. After these adjustments have been made only one mirror (plate IV) is moved and the only movement permitted is an inclination about either the vertical or horizontal axis. The whole instruments rest on four feet which are fitted with a system of springs which damp out any vibrations.

There are two optical ground plates which form the windows of the tunnel giving a field of view of 15.0 cm diameter. (These plates have total diameter of 24 cm and thickness 25 mm). These plates are the finest quality optical glass available in Germany and their surfaces are ground to less than $\frac{1}{4}$ of a wavelength of light. To compensate for the small error due to the surfaces being not parallel the two plates can be turned about the horizontal axis of the interferometer. There are also two compensating plates which form the windows of a compensating chamber through which passes the lower horizontal light beam. The light system is a Hg arc lamp of 100 watts, a high pressure Hg arc lamp of nearly 1000 watts and also a filament lamp can be used when the adjustments are being made. Three filters are provided giving light of 5461 A, 5469 - 5490 A and 4359 A wavelength respectively. The condenser (parabolic) has a focal distance of 16 cm. Finally a water cell to absorb heat rays.

For observing the fringes there is a telescope and projector on a carriage and the usual photographic equipment. Plates of 13 x 18 cm or a 35 mm film can be used. The fringes can be recorded on a moving film camera taking 100 pictures per second.

Using the 100 watt Hg arc, pictures can be taken with an exposure of 1/500 sec. The 1000 watt Hg-arc gives pictures with 1/5000 sec. exposure.

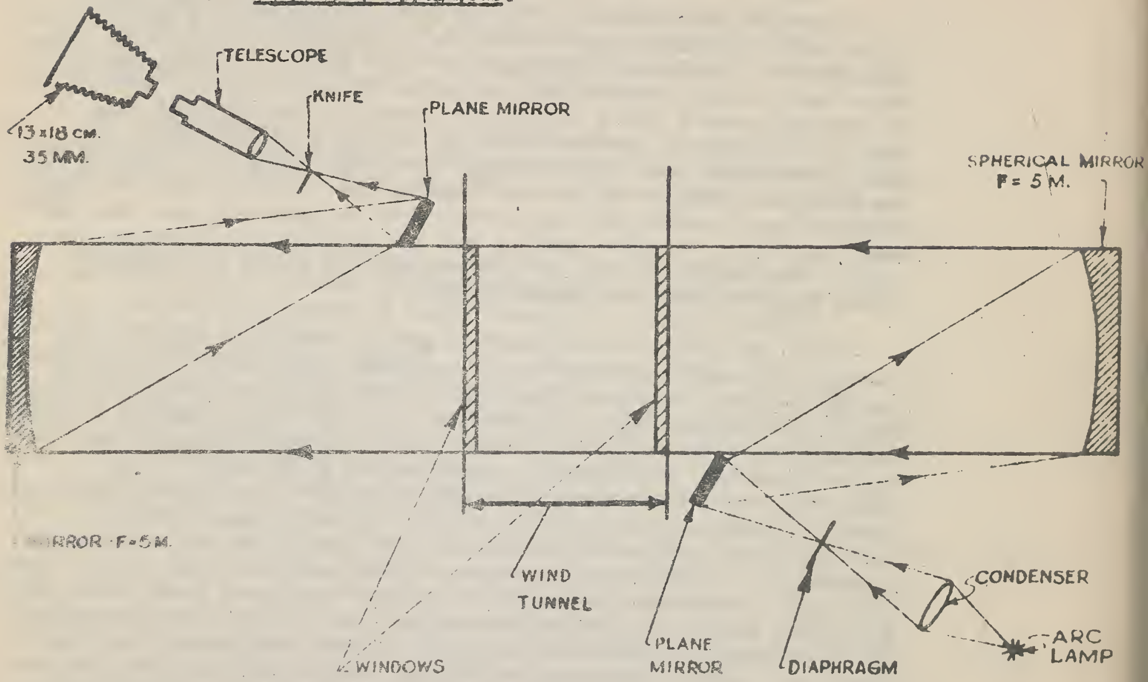
From the interference patterns it is possible to determine differences in pressure and therefore of density in the air of the wind-tunnel. The great advantages of this method are that measurements are possible without any apparatus being in the air stream, it is extremely rapid and a continuous record can be obtained with a high speed camera of models which are moving with high velocity. Special machines have been designed and constructed for interpreting the diagrams quickly and for calculating the results. One of these machines is at Kochel but the others were at Darmstadt and they have been destroyed. A other machine was in construction again and was nearly completed. As far as is known this is still at Darmstadt. (Prof. Rau, Mechanic was named Hoffman).

There is on the wind tunnel an earlier model of the interferometer. This earlier model is of the same high optical quality as the later model but the adjustments for changing the distance between the fringes is much more complicated. On the later model it is only necessary to turn one knob to make this adjustment while on the earlier model it is necessary to manipulate five knobs. This simplification of adjustments results from the fact that in the later model the length of the horizontal path is twice that of the vertical path consequently the center of plate IV is on the circumference of a circle with its center at the center of the model. There is a plan of this earlier model attached. The later model fits under the tunnel while the earlier one fitted over the top of the tunnel. The wind tunnel windows for the earlier model are larger than the later ones having a diameter of 420 mm. There are four complete windows and two sets of half plates. These plates cost more than the remainder of the interferometer.

It is claimed that the accuracy is approximately 0.5% at Mach No. 2, 1% at Mach No. 3 and Mach Nos. 4 and 5.

The following is a list of other optical equipment at Kochel.

1. **Schlieren apparatus.**



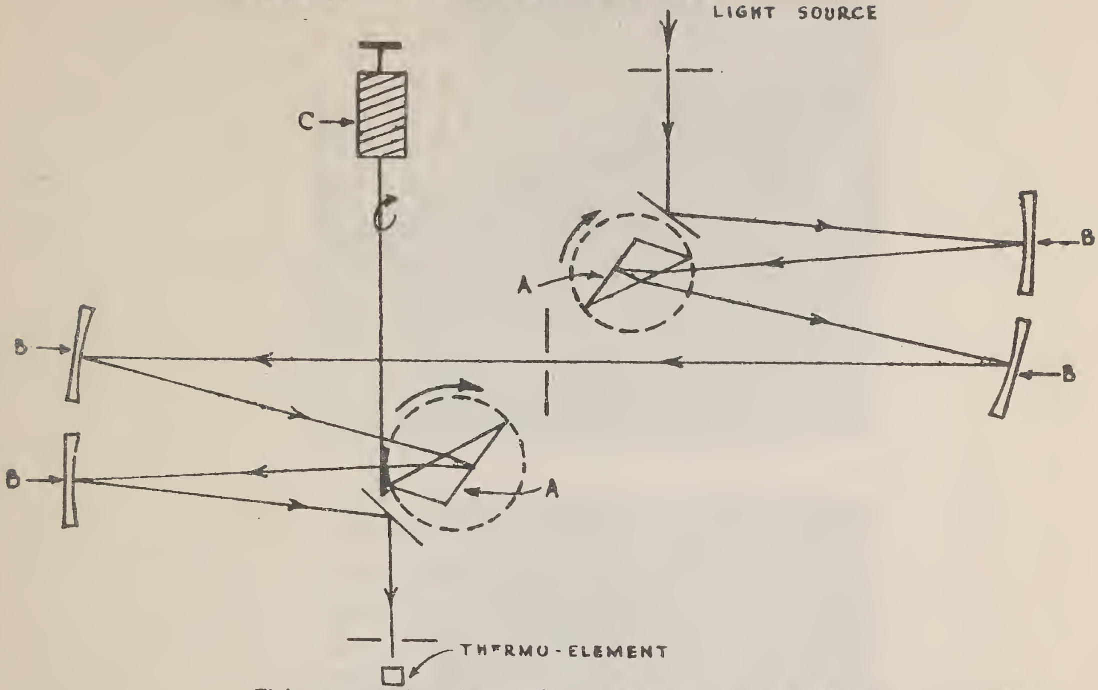
There are 2 Schlieren equipments as above, one of which is used in the tunnel. One mirror of each pair of mirrors in the tunnel spherical and the other has hyperbolic correction which is made by hand. The second equipment has two parabolic mirrors of f = 5m. The diameter of all four mirrors is 50 cm.

There is a third Schlieren equipment which uses two spherical mirrors of f = 350 cm and diameter = 33 cm.

In addition there is an equipment with two lenses of f = 250 cm and diameter 25 cm.

The usual accessory apparatus such as filters etc. are available.

2. Infra-Red spectrographic apparatus.



This apparatus is used for measuring very small quantities of water vapor in the air of the tunnel. Monochromatic infra-rays are passed through the tunnel and fall on a thermo-element which is connected to a galvanometer so that the absorption of the radiation in perfectly dry air can be compared with that in air containing a small quantity of water.

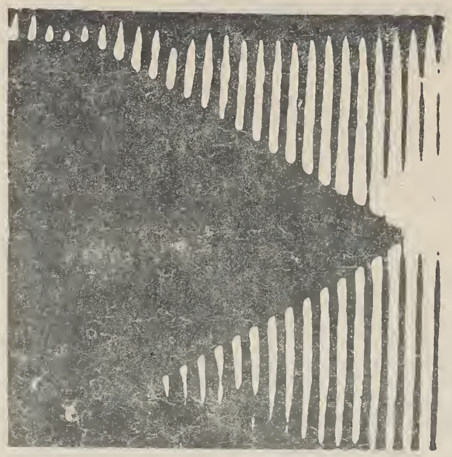
A) are two prisms of flint glass, quartz or rock-salt. They can be rotated on their mountings by means of the knob C.

B) are four spherical mirrors of f = 300 mm and rectangular shape with approximately 5 cm sides.

It is claimed that an accuracy of 1% at humidities of 0.5 gm in a cubic meter of air, and 1 - 2% at lower humidities.

It was proposed to install an alternative detector to the thermo-element consisting of an absorption cell and it was to be made so that a continuous record of the humidity could be obtained. This latter was designed but not constructed.

3. There is a complete range of smaller optical apparatus which are necessary for the measurements which are carried out and for research purposes.



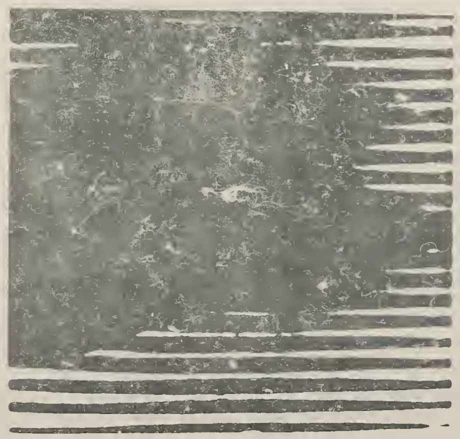
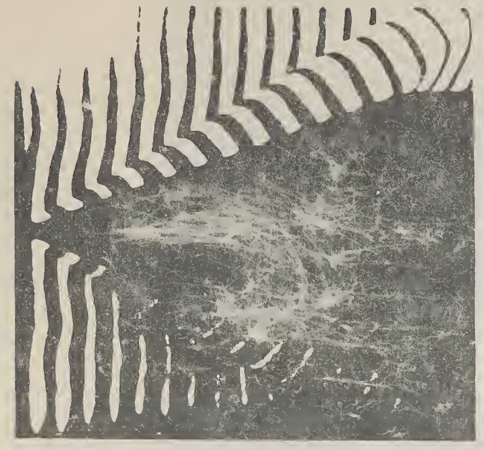


PLATE I

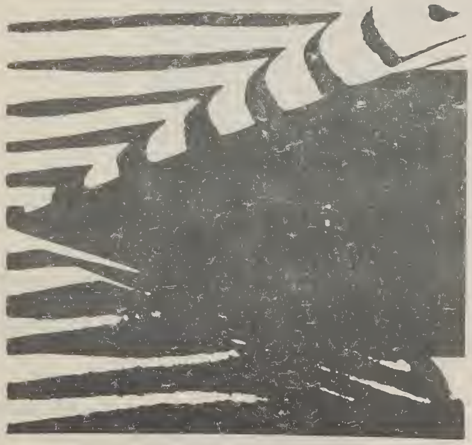
Interferometer patterns with models in still air.

(a) 60° cone, diameter of base 7.0 cm.
(b) 42° cone, diameter of base 5.0 cm.

The direction of the fringes is chosen to suit the particular model shape or a particular part of the model which is of interest.



(b)



(a)

PLATE II

(a) 42° cone in an air stream, Mach number 3.10, horizontal fringes.
(b) 42° cone in an air stream, Mach number 3.10, vertical fringes.

In (a) the patterns on each side of the cone are not the same because the pressure distribution is symmetried and the fringes always move in the same direction.

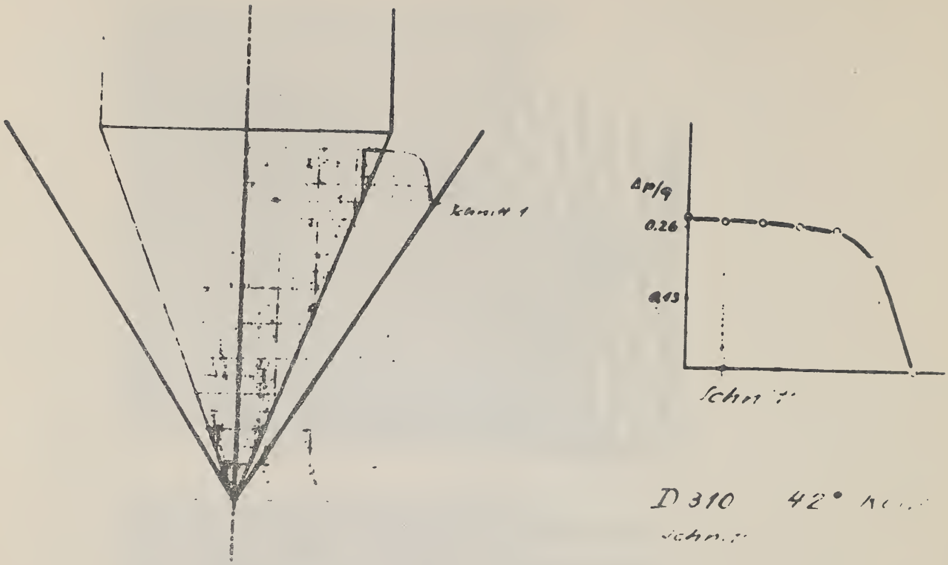


PLATE III.

Interpretation of Plate II to demonstrate the change of pressure between the shock wave and the surface of the model along the line marked "Schnitt". Mach number 3.10.

p = pressure determined from pattern
q = manometric pressure of air stream
y = coordinate along "Schnitt"

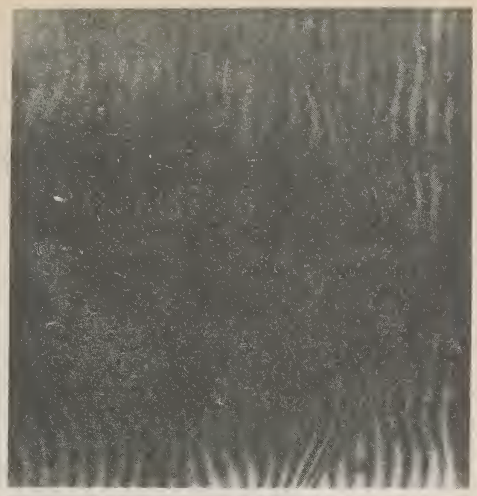


Plate IV

(a) Pattern with sphere in the air stream. Diameter 4.0 cm. Mach number 1.86 (For interpretation see Plate V)

(b) Same model as in Plate II but with wider fringes. Mach Nr. 3.10.

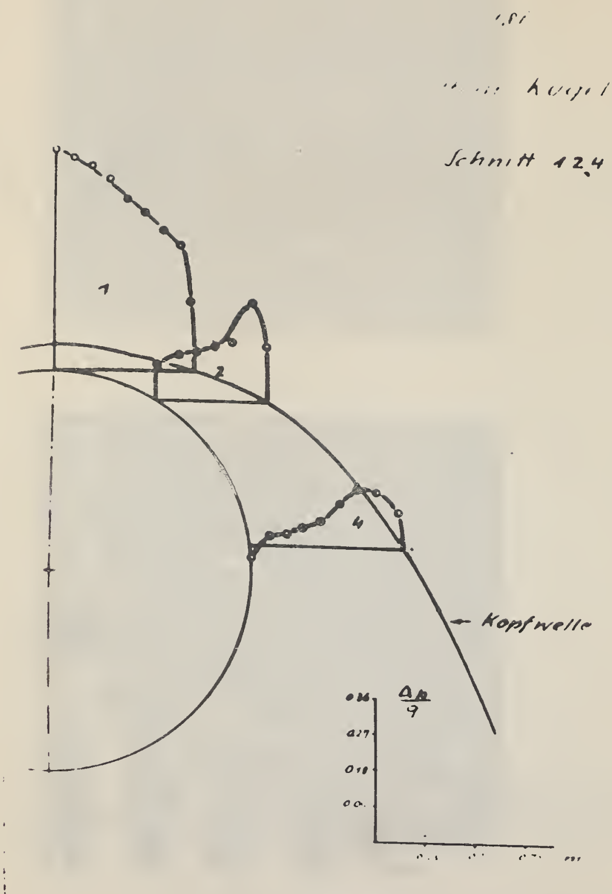


Plate I

Interpretation of Plate IV (a)

1, 2 and 4 show the pressure distribution along three lines of a section.

The scale is as shown on Plate III.

Plate VI

This plate shows the pattern obtained with Mach Nr. 1.86 without any model in the air stream.

A model giving a three dimensional picture of the pressure distribution was constructed and it enables corrections to be made to the nozzles of the air-tunnel.

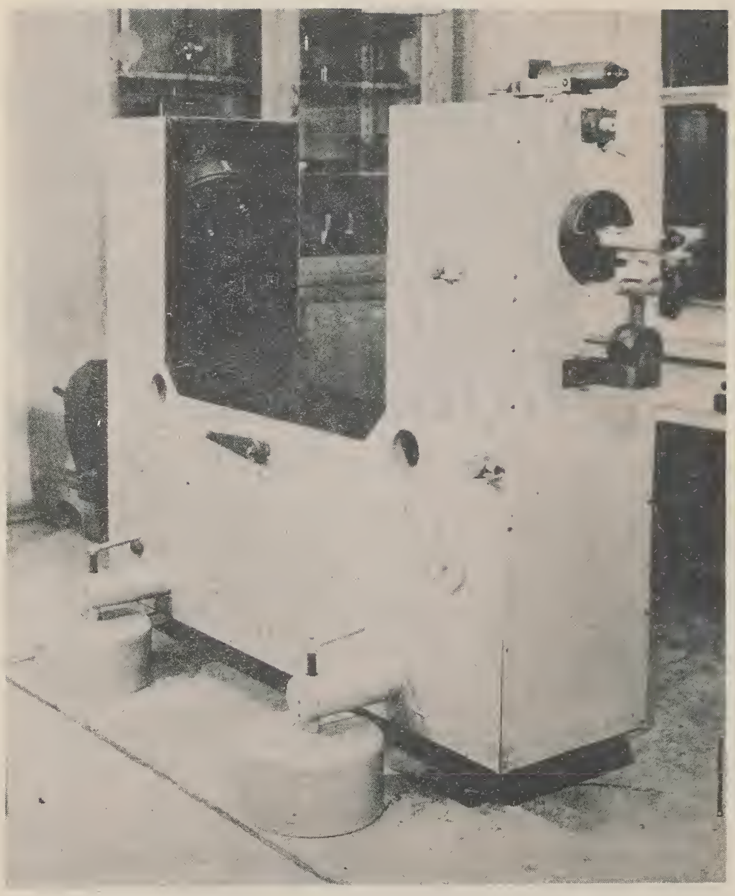


Plate VII

Photograph of interferometer showing Mirror and setting telescope (F2) in position.

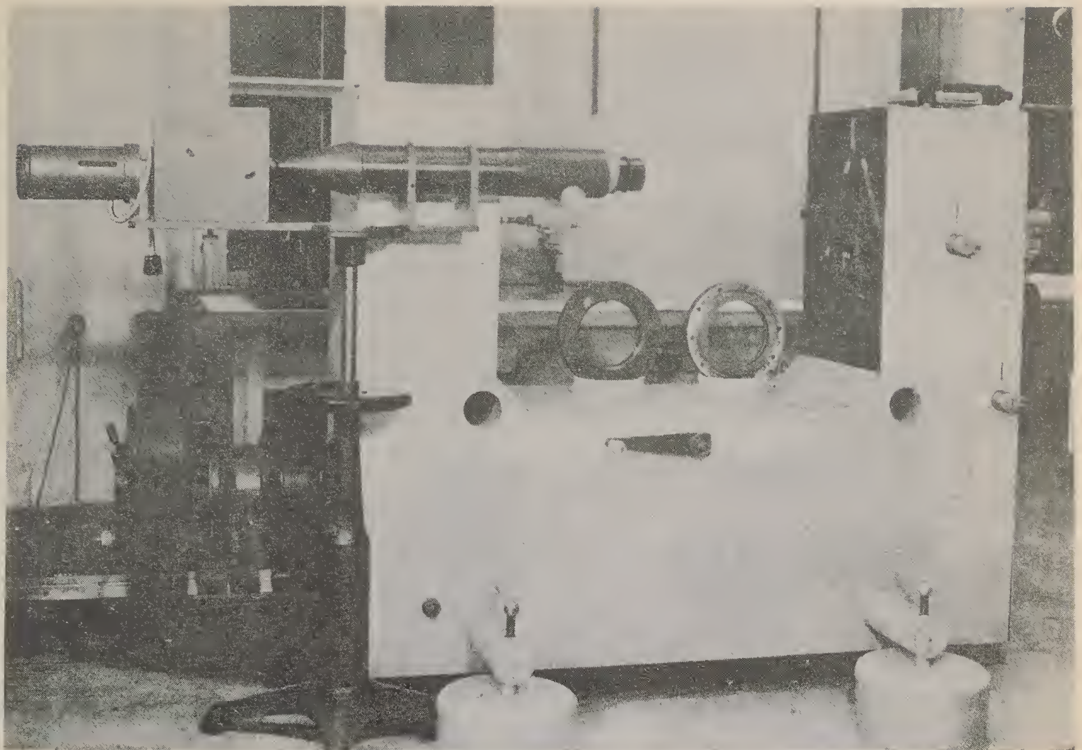
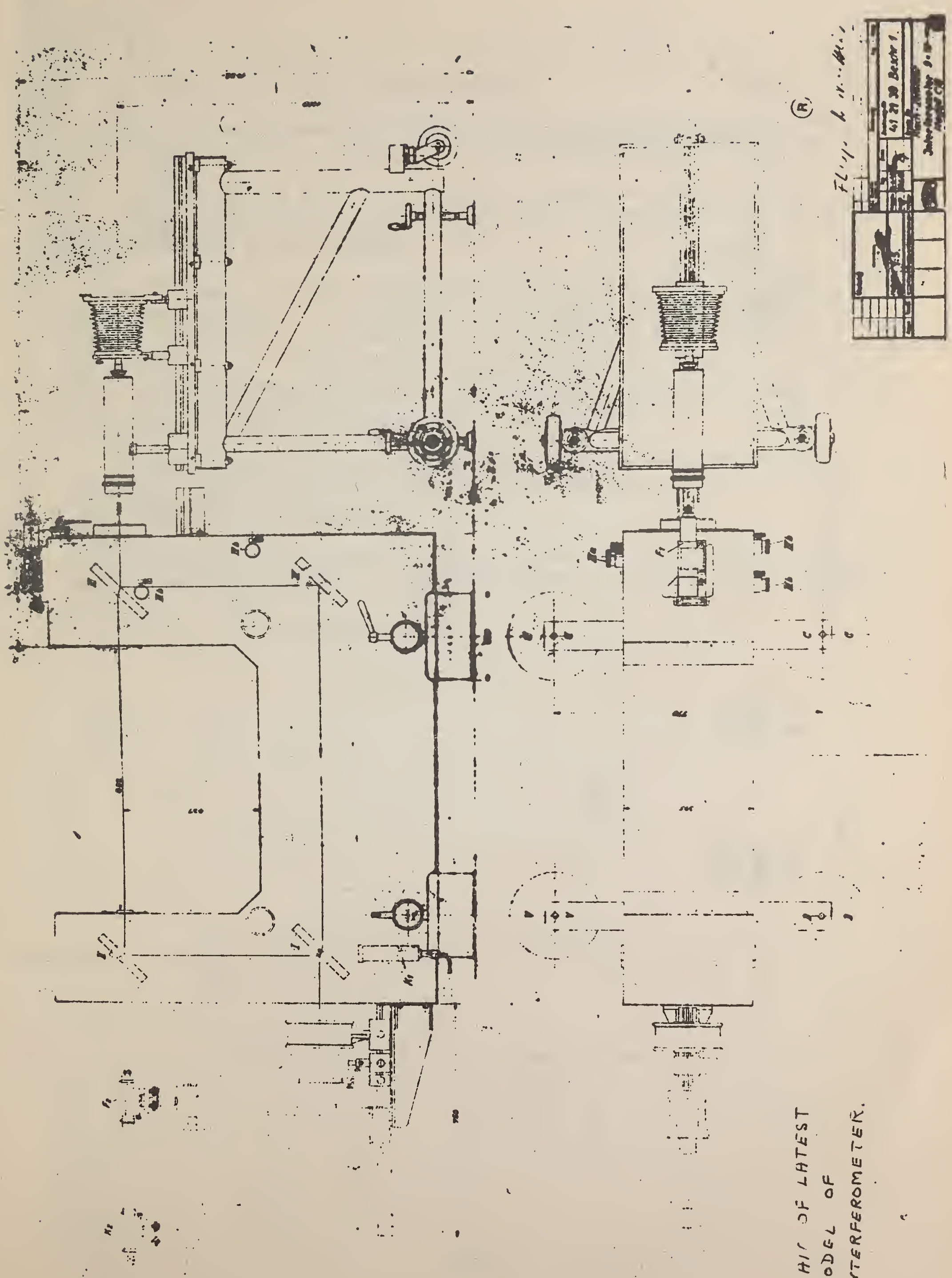


Plate VIII

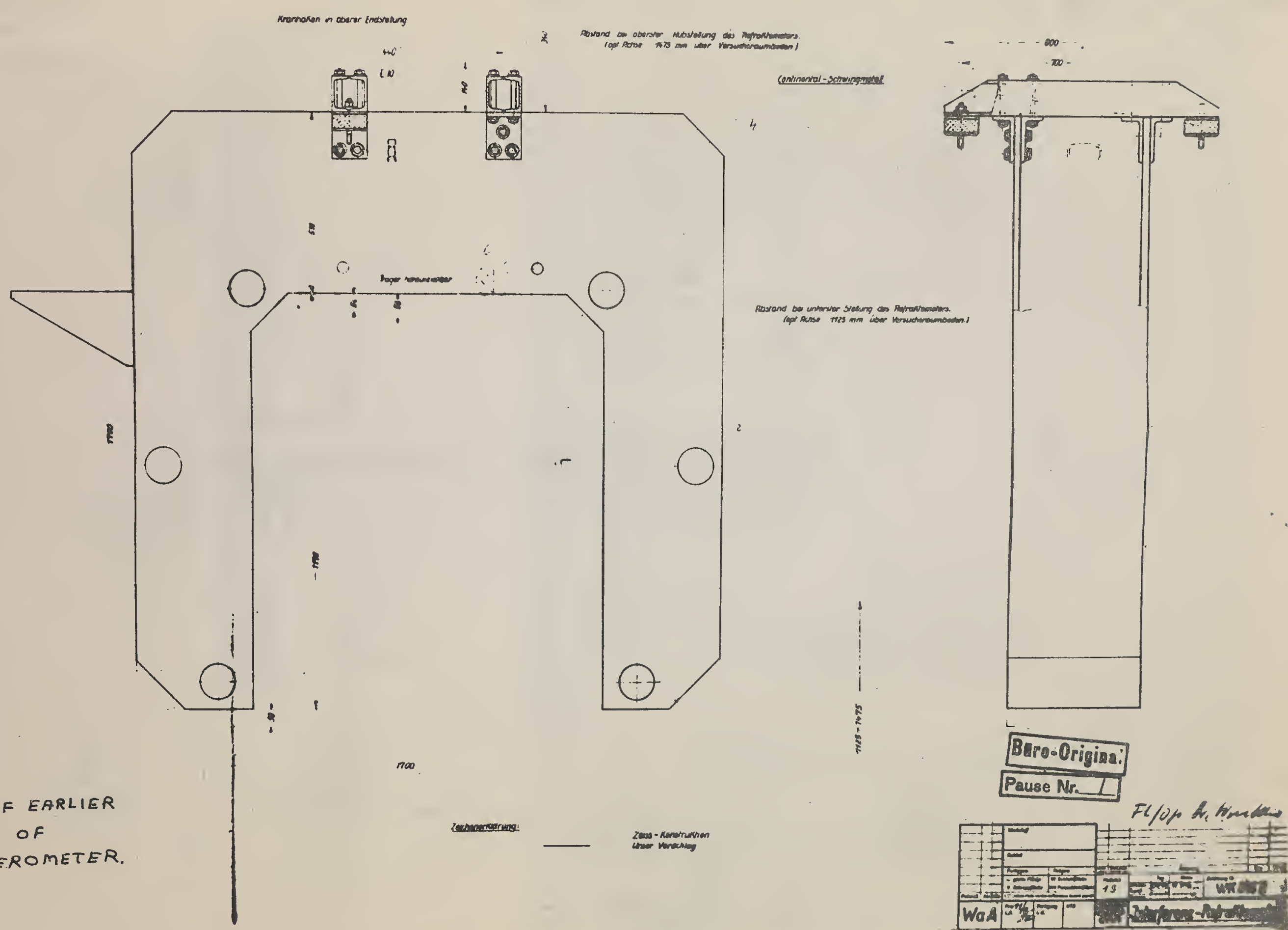
Photograph of interferometer showing Lamp system (bottom left), 2 windows and viewing telescope and camera standing to the left and in front of interferometer.

Plate II

Photograph of one of the large parabolic Schlieren mirrors with associated equipment in front.



PLAN OF LATEST MODEL OF INTERFEROMETER.



PLAN OF EARLIER MODEL OF INTERFEROMETER.

F. Production of Mirrors by Sputtering.

Mirrors are prepared by sputtering Al on clean glass and then sputtering a protective coating of SiO_2 on the mirror thus produced.

Uniformity to a half wave length is obtained; uniformity is controlled by observing interference colors - evaporation is interrupted when the proper color appears.

The cleaning is most important. The glass if first "oxidized" in air by subjecting it to a Tesla coil discharge, the ozone produced by which is supposed to be beneficial. The glass is next bombarded by ions in vacuum so as to remove and finish the cleaning. Al is then evaporated on, the heat being supplied by a tungsten filament. SiO_2 is finally sputtered on in similar fashion. The evaporations are carried out in high vacuum at temperatures estimated as 1400°C (Al) and 2500°C (SiO_2).

Al riders and SiO_2 riders are placed directly on the tungsten filament. The SiO_2 melts but the droplets adhere. About 10 sec. is the average time for evaporation.

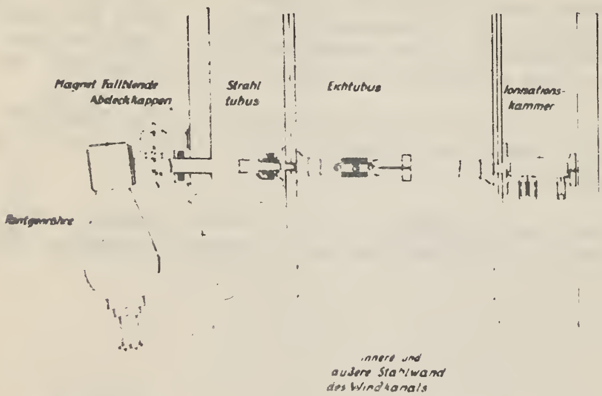
The finished mirror may be polished and is very durable. Not every mirror made is successful. Good mirrors up to about 6" diameter have been made.

G. <u>X-Ray method for the Determination of Gas Densities in Rapidly Moving Streams.</u>

Voltage constancy to within ± 0.1% was achieved by using a generator exclusively for the work and regulating its voltage by means of a standard vacuum-tube regulator (Siemens).

The schematic diagram of the apparatus is given below:

Querschnitt durch die Meßstrecke



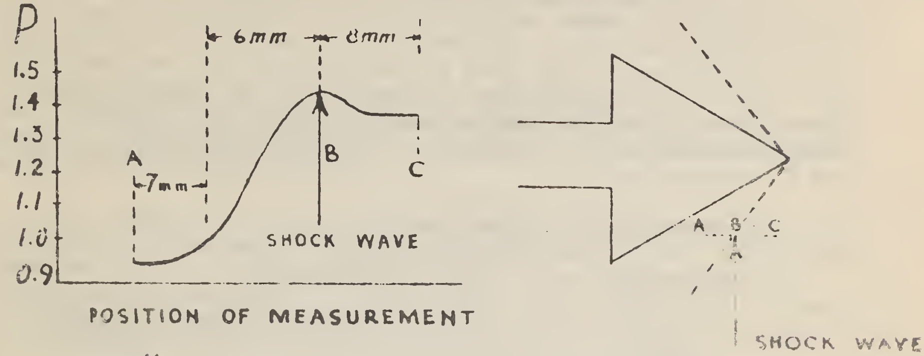
The background radiation from a W target at 7.5 to 10 kV was used; tube current 10 to 20 Ma. An ionization chamber was used. The calibration was carried out by means of the calibration tube in which known pressures of dry air could be maintained. The precision is estimated at better than ± 1% at atmospheric pressure, but it decreases with the pressure. Calibration immediately before use is advisable.

Measurements on actual models have not been made; but the method has been used to check the flow from nozzles in the wind tunnel. Flow around prisms is now being studied, and work on wing profiles is planned. The method will be more difficult to apply to projectiles and the like. On such work, the beam is stationary and the model is moved.

The ionization chamber and vacuum tube amplifier for the small currents (equivalent resistance 10^{10} ohms) were developed in Darmstadt by Rau and [illegible] (see their report HVA Archiv Nr. A1).

The method may give, for the first time, the temperature of the boundary layer for a model in the wind tunnel. The static pressure is measured as usual through a hole in the model, and the density at the same point is obtained by measuring X-ray absorption.

A typical result for flow around prisms at Mach numbers 1,6 to 2,9 is shown in the following diagram:



$$P = \frac{mm\,Hg}{°K}$$

Measurements were made at various point parallel to the axis of the model along a line crossing the shock wave as shown. There is a break in the pressure curve at this point. The decrease in pressure beyond B was not expected; it may be that some molecular process (rotation, vibration ?) proceeds too slowly to absorb the energy of the shock wave without having the pressure rise above its final value.

H. Illumination for Schlieren and Interferometer Photographs.

Four light sources are in use, as follows:

(1) A 5 ampere arc

(2) A high voltage spark source

(3) A 100 watt mercury lamp (with filter)

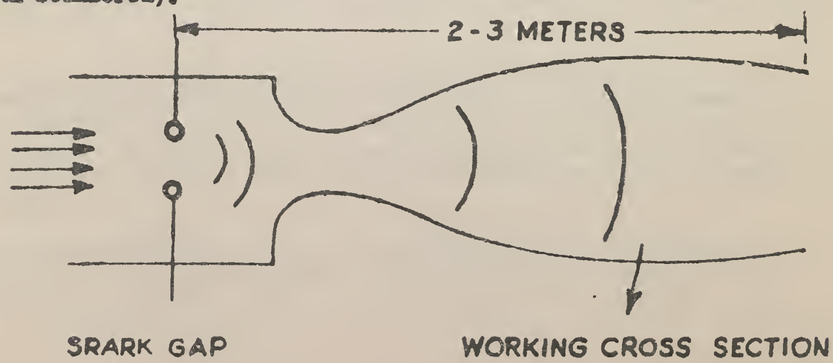
(4) A 1000 " " " " "

These light sources may be used either for the Schlieren photographs or for the interferometer, depending upon the picture desired. Light Source 3 is the one ordinarily used with the interferometer.

The usual exposure times are:

Light Source	Time (sec)
(1)	1/50 (13 x 18 cm. picture)
(1)	1/200 (24 x 26 cm. picture)
(2)	10^{-5} to 10^{-6}
(3)	1/1000
(4)	1/200

Spark illumination for the Schlieren method was being worked upon for the purpose of high intensity, excellent timing and width of the impulse of light. For instance impulses of sounds were generated up stream of the working cross section in order to determine the temperature in this cross section. (Waves made visible with Schlieren).



I. Temperature in the Wind Tunnel from Measurements of Sound Velocity.

The measurements of temperature in the wind tunnel is difficult because the air stream is moving rapidly at low pressures. The most hopeful way to get the temperature is by measuring the velocity of sound in the gas stream. The sound will move with a velocity $c + a$ (c = velocity of gas; a = velocity of sound) and the Mach angle gives the ratio c/a; sum and ratio can be obtained from two "Schlieren" photographs separated by a known time interval; the sum could also be measured by two microphones placed a known distance apart in the stream. The photographs must be about 10^{-6} second exposures.

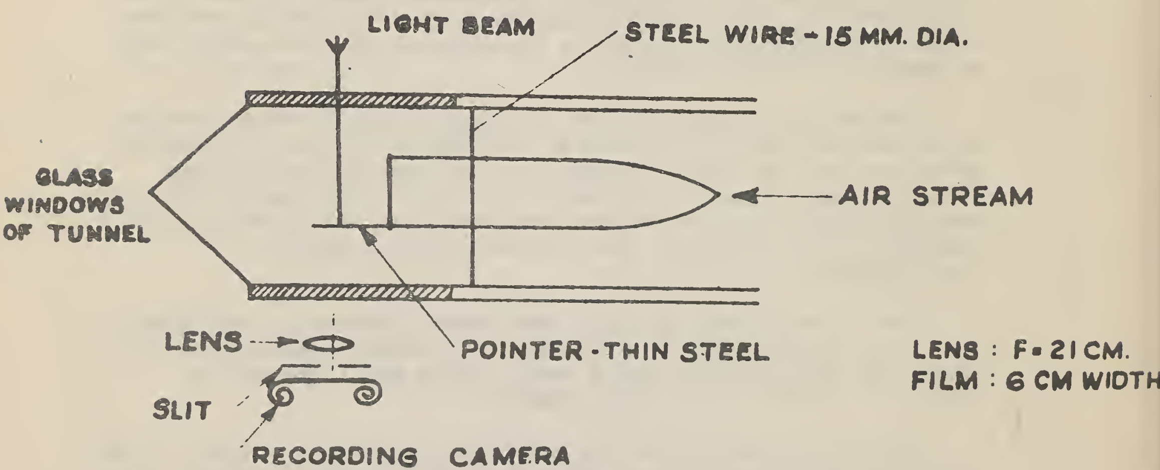
The source of sound cannot be placed in the divergent portion of the nozzle because it disturbs the flow of the gas. Supersonic vibration must be used in order to reduce the distance between successive wave fronts to a reasonable value. This method has not been successful because too much reflection of the sound occurred at the throat of the nozzle, thus decreasing the intensity prohibitively.

The following sources have been tried: piezo-electric quartz crystals; sources depending on magneto striction; and the Hartmann generator, which consists of a small nozzle and a resonating cavity. The last is the most powerful.

It is hoped to improve the method by generating a single pulse (or a short sequence of such) with a spark gap and by measuring its velocity with two suitably placed microphones. The difficulty here will lie in obtaining a sufficiently precise measurement of the extremely small time interval involved. It has been proved by using an air raid siren that sound of sufficient intensity to be picked up by a microphone can be sent past the throat of a nozzle (See Report MAP 11 Archiv Nr. 66/128)

J. Taking and Evaluation of Oscillograms of Vibrating Models in the Wind Tunnel.

The model is suspended at the center of gravity on a wire which is stretched perpendicular to the air stream. To the base is attached a steel pointer and the movements of this pointer are observed by throwing its shadow on to a continuous feed recording camera.



A time scale is automatically recorded by a trace of the 50 cycle mains voltage.

From the oscillograms the following data can be obtained: (1) Pitching moment, (2) normal force, (3) center of pressure, (4) damping.

These are obtained as a function of the angle which the model makes with the air stream.

The great advantage of this method is that the adjustment and alignment of the apparatus are simple and quick and preliminary results on stability of a model can be obtained in a matter of 10 minutes whereas with other methods it may take 9 to 10 hours. This is the only method of obtaining the damping.

Further details of the interpretation of the oscillograms and the calculation of the results may be found in a report by Dr. Wegener, dated 16/9/44, Archiv Nr. 150g.

3. Project A. Kochel.

Supersonic wind tunnel of 100 cm x 100 cm working section. Exit cross section remains constant and entrance cross section gets smaller and smaller as the Mach number increases. It was intended to get to M = 10. Installed power 57 000 kW. Maximum power necessary at M ≅ 1.5 namely 18 000 kW actual power in the jet and 24 000 kW for the compressors.

3 Filters with each 150 tons of silica gel good for one hour's operation, that is 780 000 kG air. Drying from 12 grams per kg to 0.5 grams of H20 per kg of air. The filters (dryers) work intermittently, one being dried by the clean, dry and warm exhaust air from the compressors, while the other is in operation.

Through the absorption of the H20 the heat of evaporation is liberated and the air may be heated by 25°C. In the line, because of uneven temperature of the incoming air, a cooling system to regulate the temperature is introduced (heating to 300°C was also intended for the achievement of large Mach numbers).

After the working cross section a cooler was to be installed for the case that the air was preheated. The compressors have to have relatively cool air intake. After that comes "Kugelschieber" 3 m diameter. Of these valves about 50 of these are used. Had to be vacuum tight against 1 atm. Then throttle valve (butterfly valve) so that the compressors are not overloaded by compressing air from too high an initial pressure.

Projected are 7 stages of compression.

1st stage. 4 axial blowers in parallel, each 300 000 m^3 per hour (18 rows of blades), compression ratio 1 : 2.8, 24 000 kW = 30 000 PS. Driven by two Zwillingsfreistrahlturbinen (Pelten wheels). Must be possible to regulate the power of the drive in large ranges. Between 4% and 100% it must be possible of regulation. 2 Needle valves on each Pelton wheel. About 3 000 rpm ± 3.5%. An asynchronous motor could not do that.

After the first compression the air is cooled again. Goes either to the tunnel, or to the outside air, or to the dryer, or to the second stage).

To M = 2.0 the first stage is sufficient. (Kochel was chosen because of waterpower)

2nd stage. 2 axial compressors as before, driven by one 12 000 kW Pelton turbine.
(Made by Brown Boveri Cie., not finished. Turbines made by Skoda)

The second stage has the same connections as the first stage.

3rd stage 1 axial blower of exactly the same dimensions as before. (Whole compression 1.5 mm Hg to 760 mm Hg).

4th stage centrifugal compressor because air is now dense. (4 stages) ratio 1 : 3. 150,000 m^3 per hour.

5th, 6th & 7th stages all centrifugal compressors.
Pelton wheels. Total of 4,500 kW. Each is compression ratio 1 : 3. Theoretical total is 2,400 for the total compression ratio. Practically 550

With M = 10 one needs a total power of 200 kW only. One needs the whole expensive installation for two reasons.

(a) to cover the whole range in M and
(b) not to have a tremendous installation (If one needed only one Mach number one could use a large machine of small power).

4 independent working sections are installed.

M_1 = working section 1 1.4 m x 1.4 m
M_2 = working section 2 1 m x 1 m
M_3 = working section 3 0.4 m x 0.4 m
M_4 = working section 4 0.25 m x 0.25 m

M_1 = can use all stages
M_2 = can use all stages

M_1 and M_2 must be run separately.

M_1 can be run over the first two stages and
M_3 at the same time over the last five stages.

Many other combinations possible.

Three buildings

(1) Power plant
(2) Wind tunnels, working sections
(3) Dryers.

The radial compressors have 4300 to 9400 rpm.

The big Pelton wheels have 300 rpm and the small ones 428 rpm.

Total installation, water power station, wind tunnels and power house etc. 25 000 000 - RM

Dec. 1943 project started. Time for construction 1½ year.

Extensions to the present supersonic wind tunnels.

At present vacuum cylinder = 750 m^3
" " sphere = 1000 m^3

Also 6 rotary piston pump (Rotations compressor)

With this aggregate one achieves a duration of the jet of between 24 seconds and 38 seconds between M = 1 and M = 4.4

It was intended to add three centrifugal blowers with which the duration of the jet would have been as follows.

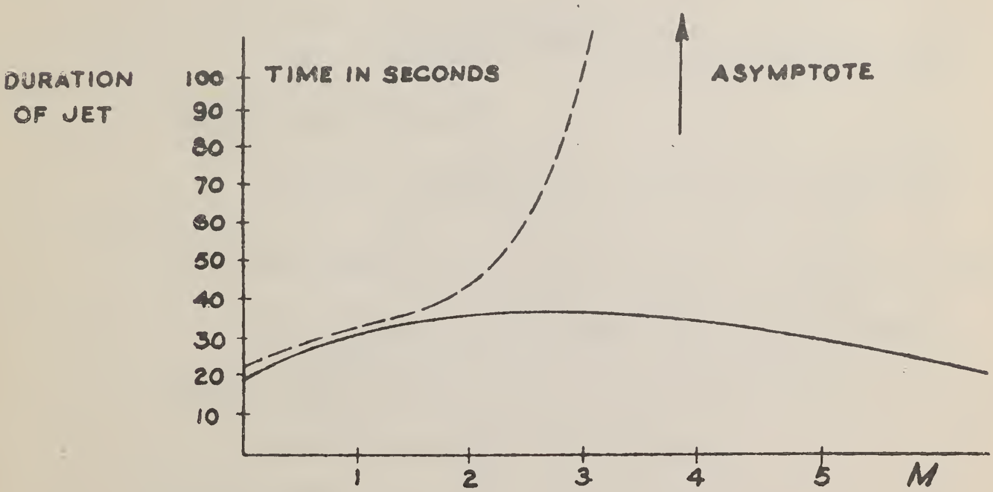
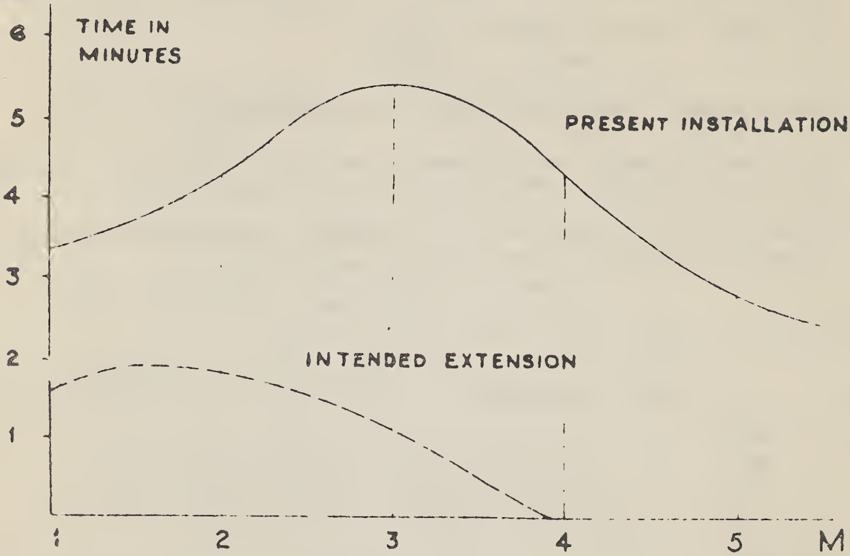


Diagram for cylinder + sphere

present + 3 centifugal blowers. (850 kW each)
present installation

(continuous operation would have been possible for M 3.9).

eriods necessary for evacuation of cylinder + sphere run as follows:



Additional advantage of the centrifugal blowers is oil free air, usable for regenerative operation.

(The valve and conduits are not available).

For further details of the extension project see Dr. Eber's report.

4. Other supersonic wind tunnels in Germany:

1) In Aachen (now in Sonthofen in the Allgau)

   (a) 20 cm x 20 cm up to M = 1 (Wieselsberger)
   Jet of about 5 seconds duration.

   (b) 10 cm x 10 cm for intermittent operation.
   10 seconds operation up to M = 3. This working section was note yet in operation.

2) Göttingen

   (a) wind tunnel 20 cm x 20 cm intermittent operation for transsonic region, duration not known.

   (b) 13 cm x 15 cm (supersonic)

   (c) 30 cm x 30 cm or 40 cm x 40 cm intermittent projected.

3) Braunschweig-Volkenrode.

   (a) 40 cm x 40 cm supersonic wind tunnel with intermittent operation. No balances. Only pressure distribution.

   (b) 20 cm x 20 cm supersonic, continuous operation.
   No balances.

   (c) Tunnel with 1 m Ø circular section for tests in the compressible subsonic region until M = 1. Continuous operation.

   (d) Tunnel with 1 m x 1 m cross section for supersonic tests up to M = 2. Continuous operation.

4) Munich LFM

   40 x 40 cm tunnel in construction.

5) DVL LFM

   40 x 40 cm tunnel planned.

5. Reports of the WVA

(1) There exist on transparent paper (vellumtype) about 168 original reports from 1939 until now. A complete list of the reports is available at Kochel. Microfilm also exists which covers all of these reports.

(2) About eight folders of "Professoren Berichte" are in the library. These cover partially the theoretical work which was farmed out to the Professors at Darmstadt and other Universities. (They are mostly concerned with the interpretation and application of wind-tunnel tests. (Peenemunde Ost).

(3) About 80 reports of the ZWB = Zentrale fur wissenschaftliches Berichtwesen der Luftfahrtforschung.

Reports generally are of three types:

(a) Reports for the benefit of other investigators or construction agencies who had subcontracts from Peenemünde.

(b) Extensive reports on individual subjects.

(c) Reviews for didactic purposes.

6. Discussion of the efficiency and possibilities of the supersonic wind tunnel installation of the WVA.

By Dr. R. Hermann.

SUMMARY

This discussion covers the possibilities of the WVA and the successes already attained by its supersonic wind tunnel installation. It is sufficient to give quick information on the main scientific and technical subjects.

Section A gives a survey over the fundamental considerations especially regarding the capacity of performance of the supersonic wind tunnel installation.

Section B states the performance capacity of the operating supersonic wind tunnels.

Section C describes the large and specially designed measuring equipment.

The performances of the other German supersonic wind tunnel installations are discussed in the Section D, while Section E contains calculations about a possible raising of performance of the present wind tunnels by enlarging the pump section of the plant.

In particular:

Section A states that the present supersonic wind tunnels have been construsted especially with the regard to the establishing an up-to-date installation of high performance capacity. It should be able to meet all requirements of the supersonic area, all problems of high-speed-projectiles and aircrafts with the top of accuracy attainable within the shortest time.

A retrospect on the development of the institute shows in what a manner it developed from a mere wind tunnel installation to a complete research plant including different laboratories, construction offices, work and machine shops.

A summary of the special details of the whole installation emphasizes the fact of its performance capacity.

Section B particulars of the present operating wind tunnels and the additional equipments as vacuum-reservoirs, the vacuum pump system and its power supply, the air drying installation as supposition for exact measurements in supersonic flow. An added survey considers the effective work done at the measure chambers in comparison with other laboratories existing in Germany.

Section C treats the performance capacity of the measure equipment most of it being especially designed for the supersonic wind tunnel use. The three component balance, the Schlierenapparatus, the

interferometer and the methods of measuringthe pressure distribution on models of projectiles and missiles flying at supersonic velocity as well as special devices as electric operating pressure distribution doses, balances to be installed within the models themselves, and last but not least a high voltage spark outfit - they are all subjects of explanation.

Section D speaks of the other supersonic wind tunnels installations in Germany. There are particulars as sizes, shapes and the outfits and their possibilities are revealed as well as their performances capacity.

It results that the WVA installatiàn shows itself superior to all other German plants with respect of highest velocity at greatest areas section of the stream attained on the one hand and measuring equipment and inserted methods on the other.

Section E finally discusses the possibility to improve the performances of the wind tunnels at Kochel by enlarging the machine installation. According to calculations a continuous operating at Ma number above 3,9 at the entire cross section (40 x 40 cm) would be attainable as well as double the time for a single run in intermittent operation at lower Ma numbers.

The gain of time while carrying out long series of measurement would be pretty considerable as a consequence of the shorter vacuum pumping period due to the enlarged machihe sets.

A. Basic Points of View of the Efficiency of the Supersonic Wind Tunnel of the WVA.

With the development of air techniques in Germany in the last 10 to 15 years it had been chiefly proven that the research stations, e.g. wind tunnels although they show very good basic work could not keep up with the pace demanded by the Government or industry. The technical developments had therefore to be condusted on a multiple scale without the necessary support of research and at times set-backs could not be avoided.

When Dr. Hermann (the originator and Director of the WVA) was entrusted in 1937 with the construction of a supersonic wind tunnel installation at Peenemunde for the Heereswaffenamt, he decided to circumvent these mistakes as much as possible. His object was to build up an aerodynamic-ballistic research station which would be in the position to supply the necessary aerodynamic research apparatus for the numerous developments in the sphere of fast flying rocket projectiles, rocket aircraft and other fast rocket projectiles which were already being anticipated at that time. In constructing the supersonic wind tunnel he placed first and foremost the principle of obtaining the highest possible efficiency for the installation, in order to complete the numerousdevelopments with the greatest number of series tests.

After completion of the installations in 1939 it proved to be entirely a match for the fast pace in the development of supersonic projects. Almost all the developments of this kind in Germany from 1939 to the end of the war in 1945 were worked out in this installation. The solution of these problems was possible owing to the fact that in the construction of the supersonic wind tunnel installation and the measuring apparatus, not only were the points of view of scientific demands taken into consideration, but an unrestricted technical set-up, of every testing, measuring and operational device of any great value was installed. This enabled the scientists to pursue their experiments with the necessary concentration, deep research and rapidity without the inconvenience of improvised experimental apparatus or other difficulties.

Moreover the station was soon equipped with a series of physical, optical, thermo-dynamic, and electric laboratories, which is not the case at other wind tunnels in Germany. They are occupied by Specialists of different faculties whose duty it is to develop up-to-date methods of measuring and measuring apparata, which are necessary for the solution of difficult test problems in the supersonic wind tunnel. A special designing office and efficient workshop saw to it that the ideas and suggestions of the scientists on measuring techniques were immediately put into technical form, and in the shortest time produced in a mechanically unrestricted manner. For this purpose a range of specialists trained for the work and doing work for the supersonic wind tunnel for a long time, were attached to the designing office and workshop.

The characteristics of the efficiency of the supersonic wind tunnel installation of the WVA • can be summed up as follows:

(1) Greatest air speed (Mach No. 4.4) which to our knowledge has ever been reached in Germany or even in Europe at the same time as the greatest flow section (40 cm x 40 cm)

(2) Greatest versatility for preparing scientific and technically good measuring methods and devices for the solution of difficult experimental problems.

(3) Research problems placed by the Government or Industry could be carried out in the quickest possible time.

In the following sections a detailed description of the experimental apparatus and measuring devices is given, which are necessary for the efficiency of the Institute, and a comparison with other supersonic wind tunnels which are to be found in Germany.

As an example of the efficiency of the supersonic wind tunnel installation of the WVA and the recognition it received, the following example will do:

In the spring of 1943 the development of the rocket-projectile "Wasserfall" was commenced by the RLM at great expense. This was a flying device to be fired from the ground at an enemy bomber, controlled on all three axes with a speed of 1200 m/sec. After exhaustive testing by the representatives of the RLM, the Research Council (Forschungs fuhrung) and the Heereswaffen it was established that in no other supersonic wind tunnel (Gottingen, Aachen, Brunswick, Volkenrode) could the extensive and new kinds of aerodynamic experiments demanded be carried out with the necessary versatility, deep research and rapidity. All the aerodynamic development of these first supersonic rocket aircraft were undertaken only by the WVA. After about 15 months work the development was concluded and all the set problems solved.

B. Efficiency of the Supersonic Wind Tunnel of the WVA.

(1) Measuring Sections and Vacuum Sphere.

The execution of all the experimental tests at high speeds resulted in the so-called measuring distance. At the present time there is in operation at Kochel a measuring distance with a jet section of 40 cm x 40 cm. With this speeds with Mach numbers of 0.5 to 4.4 can be obtained. In the supersonic region there are 7 different Laval nozzles with which the following Mach numbers can be attained: 1.22, 1.56, 1.86, 2.50, 2.90, 3.24, and 4.40. All the nozzles have been calculated according to the Prandtl-Buscmann process for potential current and corrected by subsequent consideration of the boundary layer and with the help of the Schlieren process for unrestricted parallel currents. Speed and pressure distributors lie at the front of all the nozzles. In the compressible subsonic region the speeds with Mach Nos. 0.5 to 0.85 or 0.90 can be obtained. With the vacuum sphere of 750m^3 at present in operation at Kochel the trial time in the supersonic area is about 15 seconds. In the subsonic region it is longer. A second vacuum sphere of 1000 m^3 capacity was likewise to be erected at Kochel. It was transferred from Peenemunde. Its completion was delayed, because the butt joints necessary for riveting the sheet metal of the sphere could not be procured in West Germany on account of the air raids. They are with a firm in Brackwede near Hanover. With their arrival (weight about 10 to) the second vacuum sphere could be put into operation in about two months. With this second vacuum sphere the testing time would be increased from 15 to 35 seconds approximately. This is of special value for difficult measuring, e.g. pressure distribution measurements at the highest Mach numbers.

A second measuring section with a flow section of 40 cm x 40 cm was in operation at Peenemunde. This has been brought to Kochel, and its completion could coincide with the completion of the second vacuum sphere (about 2 months). This measuring section is equipped like the first for all supersonic speeds. After completion of both measuring strips and both vacuum spheres, either one of the measuring section could be used with both vacuum spheres to obtain the increased test time as mentioned above, or both measuring strips could be operated with separate spheres for short test times.

A third measuring section has a flow section of 18 cm to 18 cm. It can be continuously operated with the existing machine installations. It was already in operation at Peenemunde up to a Mach number of 3.3.

The corresponding conduits and buildings have already been produced. They could be put into operation in about 3 months, as an air-drying apparatus still has to be built. In this measuring section all tests should be conducted which require longer time to obtain the specific conditions of stability (e.g. heat transformer tests, pressure recovery in diffusers).

A fourth measuring section for stationary operation for attachment to the same machine installation was likewise already in operation in Peenemunde. It was destroyed during the moving. However, in accordance with experience gained in the meantime, it has been redesigned and could be built in the WVA workshop. It will have measurements of 15 cm x 15 cm and is intended as a laboratory measuring section for the examination of special problems, not for the completion of series measurements. Its construction was to take place in a specially small test room. The conduits of the vacuum sphere had already been laid there. It is useful for various types of problems, vertical as well as horizontal. Also for example, important measurements of the jet and of the diffusor are obtained in order to work out with the basic tests the form of the measuring strip. For the tests of higher Mach numbers it is specially vacuum proofed.

(2) The Machine Installations.

The vacuum necessary for the generation of air speed in the vacuum sphere is produced by 6 vacuum pumps with a driving capacity of 800 kW. To obtain different high vacuums the pumps can be connected as desired either parallel or behind one another. The whole machine installation in addition to valve control is provided with automatic remote control, safety and warning devices, which guarantee great ease in service when carrying out tests and safety in operation. In actual fact during 6 years operation of the sensitive and complex machines no serious damage has been incurred. As a further 600 kW electric capacity is necessary for the air drying apparatus to be described later, it is important that the total capacity of 1400 kW is obtainable at all times with certainty. In Kochel this capacity could be drawn upon at will, as the WVA has built its own transformer station of 100 000 to 600 volts for this purpose durect from the Walchensee Power Station and is supplied with its cables.

Actually the installation in Kochel always had at its disposal the necessary electric capacity.

Other wind tunnels were considerably retarded in their operations by the current being cut off. For example, different wind tunnels in Brunswick, Volkenrode only received the necessary capacity for a few hours during the night. Such limitations are naturally very restrictive for a planned test operation.

(3) Air Drying Installation.

According to extensive tests in 1935/6 at the supersonic wind tunnel which Dr. Hermann constructed at Aachen it was found that unrestricted measurements at supersonic speeds can only be carried out by using dry air. The drying must be carried out more extensively for increasing Mach numbers. The WVA have at their disposal an air drying apparatus of 600 kW capacity, which was developed specially for the purpose of attaining a high degree of air dryness for high Mach numbers during uninterrupted test operations. It is the only one in Germany. The supersonic wind tunnel at Brunswick-Volkenrode with flow section of 25 cm x 25 cm and 40 cm x 40 cm possesses no air drying apparatus whatsoever. The small supersonic tunnels at Gottingen (11 cm x 13 cm) and at Aachen (10 cm x 10 cm) can dry the air with a single stage drying apparatus up to 2g/kg, while the Kochel installation with 2-stage drying can achive 0.2g/kg, a value which is demanded by high Mach numbers. The drying installations in operation at the WVA supply both large measuring sections at the same time. They also supply the 4th measuring section. A special air drying apparatus is necessary and in construction for the third measuring section with its continuous operation. The buildings and the essential mechanical and electrical parts are already available. It can be completed in three months.

(4) Hours of Operation.

In Peenemunde as well as Kochel the measuring sections were worked in two shifts in all about 18 to 20 hours. A survey of the efficiency of the installation gives the actual operational hours of the wind tunnel. They are given as pure "productive" wind tunnel hours of the two-shift working time after deduction of all time taken for the setting up of models and measuring apparatus, for alterations and the preparation of the measuring sections of the operational devices. With the existence of one measuring section the "pure productive wind tunnel hours" amounted at Kochel to an average of 200 hours per month, maximum 250 hours after the transfer in the winter 1944/45. At this time difficult working conditions such as the extreme winter cold, the lack of heating, black-out, air raid warnings, and difficulty of providing for those in attendance at night have to be taken into consideration. By contrast, before the removal about 500 "productive wind tunnel hours" were achieved a month at Peenemunde in the years 1941 to 1943 using 3 measuring sections.

There can be no doubt that the supersonic wind tunnel installation of the WVA with its operational assurance and the number of operational hours is far above the other supersonic wind tunnels in Germany. According to precise figures of their installations and methods of working only a fraction of these figures could be achieved there.

made during the blowing in order to follow interesting phenomena (e.g. compression thrusts). The Schlieren apparatus can also be used as desired in both large measuring sections of 40 cm x 40 cm in the same test chamber. It is therefore constructed as a large centilever carrier, so that in the most simple manner it can be raised up from one tunnel with the crane of the test chamber and fixed in the other. For the measuring section of 18 cm x 18 cm in continuous operation a Schlieren apparatus of 30 cm is provided, the optical parts for which are already available at Kochel.

For the fourth small measuring section a corresponding Schlieren apparatus is likewise in hand.

Schlieren apparata are likewise used in all other supersonic wind-tunnels in Germany. The extraordinary optical sensitivity in large fields of view in the same way as the good tenchical construction, which makes possible an exact, rapid and convenient work, was constantly recognised without reserve by the representatives of the other supersonic wind tunnels in Germany in the personal exchanges of experiences.

c) The Interferometer.

In addition to the Schlieren apparatus an interferometer has been in use since 1943 with a field of view of 9 cm x 10 cm (mirror diameter 20 cm). A simple apparatus has only been in existence at Brunswick-Volkenrode. With the help of this it is possible to propose quantitative evaluations of the field of density of the two dimensional flow. At WVA for the first time an exact process for the evaluation of rotationally symmetrical fields of flow was developed and brought into use with the interferometer by avoiding approximate iteration methods. Owing to the removal from Peenemunde to Kochel only the practical use of this process was delayed. A second interferometer still more simple to operate and of the same size has been at their disposal since 1944 so that in the future it would be possible to work two measuring sections with an interferometer at the same time.

(2) Special Measuring Devices.

In addition to the general measuring instruments, which belong to the wind-tunnel itself, there is also in existence a range of special measuring devices, which are either connected with models tested from time to time, or are only used in special cases. These are for the most part developed in the laboratories and designing dept. of the WVA and constructed and completed in the workshops of the WVA. To these Belong:

a) Pressure distribution measurements.

The carrying out of pressure distribution measurements on models of all kinds (bodies of projectiles, wings, rocket projectiles, and rocket aircraft) is of varying importance, as only in this manner can the details of the course of flow on models be ascertained, and used for a statical calculation of the necessary fundamentals in design.

C. Efficiency of the Measuring Apparatus of the W.V.A.

(1) General Measuring Apparatus.

a) The weighing-machine.

The most essential measuring apparatus for the determination of the drag, lift and torque or aircraft models is the three component balance. Both the large measuring sections of 40 cm x 40 cm flow section possess a three component balance with an electrical distance indicator. The balance represents the experience of long years of development, which Dr. Hermann began on similar balances in the supersonic wind tunnel at Aachen 1935/36. It is to be stressed that all the parts of the balance are situated in a pressure-proof chamber and connected outside only by a cable to the electric indicating instrument. The sensitive regions can be change by a simple current reversal of the electrical parts. All levers connections and sockets are fixed with flat springs and steel bands, with which a strong mechanical performance with great sensitivity and accuracy is created. The angle of attack can be adjusted electrically from outside, during the time the supersonic air-current is being blown through without opening the measuring chamber, which results in a considerable acceleration of the testing operation. The balance has proved itself to be the best in long years of rough experimental operations. An essential improvement for convenience in handling would be the introduction of a lineal indicator recording apparatus which is in preparation.

Of the other supersonic wind-tunnels in Germany only the small measuring sections of Gottingen and Aachen have at their disposal three-component balances, while the large measuring sections in Brunswick-Volkenrode have no three-component balance.

b) Schlieren Apparatus.

Many tests require the observation of models moving in the air current of the observation of the fields of current, by means of optical apparatus; so that the models can be adjusted. For this purpose the measuring chamber is provided with glass windows which afford a completely free view in the horizontal direction. In this manner it is possible to make flow visible on its course through the Laval nozzles to the model with the help of the Schlieren apparatus or the interferometer. The Schlieren apparatus has a field of view of 50 cm diameter, so that the flow at the tip and the stern can be observed at the same time even with the largest models (40cm). Cinematographic exposures can also be made with time lenses, if the occasion arises. The Schlieren apparatus was supplied by Zeiss (1937/38) according to WVA's own optical calculations, and was at that time the most sensitive instrument that Zeiss had ever constructed. On this technical set-up corresponding to the principle of efficiency the great value of the whole supersonic installation lies. The Schlieren apparatus is situated lengthwise in the measuring chamber as well as at the top of an electrically adjustable undercarriage, in order to bring every point of the measuring chamber into the center of the field of view. Adjustment can also be

A method has been worked out by the WVA which permits 100 pressure borings – measuring points to be taken at the same time on the model up to Mach number 4.4 in a 15 seconds test. For this multiple manometer with suitable pre-evacuation available, for example about 120,000 measuring points on the bodies and fins of the A4 were measured in this fashion. The measuring took only 14 days and by day and night shifts at times 30 to 40 measuring personnel were required. The calculated evaluations took 3 months. In no other supersonic wind-tunnel in Germany have pressure distribution measurements been conducted in this fashion.

b) <u>Electric Pressure Measuring Boxes</u>.

For measuring non-stationary behaviour on models or in the wind tunnel itself, electric pressure measuring boxes of various sizes and sensitivity, have been developed by the WVA with the help of Prof. Kuster of the High School Institute, Darmstadt. With this apparatus important information has been gained concerning the structure and breakdown of the supersonic flow.

c) <u>Stability Measurements</u>.

The measuring of stability in air techniques and ballistics of all flying bodies has great significance. One can say without exaggeration the technical realisation of controlled high-speed flying projectiles or aircraft depends in a different manner on the very precise knowledge of aerodynamic stability, i.e. the center of air forces. For the most exact determinations possible of the center of air forces for different shapes of bodies at all velocities and angles of attack several methods of measuring and measuring devices have been developed and tested over a long period by the WVA. They are supplemented and controlled reciprocally. In addition to the usual aerodynamic determination of the center of air force by three-component measuring on fixed models the following have been specially developed by the WVA:

Stability measurements on models oscillating freely in large amplitude with simultaneous registration of the fading out curve of the oscillation for the resolution of the center of air forces, moment and air damping, stability measurement on models, which are movable around a fixed rotation point with very small amplitude inside of which by displaceable weights the arbitrary mechanical moments can be given.

Stability measurements on models, which are movable around a greater number of arbitrarily changeable turning points with very small amplitude in which every turning point is at the same time the center of gravity.

In the other supersonic wind tunnels in Germany similar stability tests have not been carried out with such accuracy.

d) Built-in balances.

Important measuring devices for ascertaining moment, which are used on the model, are the balances which are built into the models themselves. This is the best way in which to exclude actual air forces and moments from stationary instruments. With the smallness of models (app. 4 cm diameter, 30-40 cm long) extraordinarily delicate instruments from the point of view and design are used. To these belongs the so-called spin balance of the WVA, which makes it possible to measure moments along the longitudinal axis of the bodies to an accuracy of 1 cmg. The resolution of these roll moments is necessary with aircraft or rocket projectiles, as they appear with unsymmetrical construction or during flight with a side wind and must be balanced out.

The designing, construction and testing of this balance took about a year. It was installed with success during the development of the A4 and "Wasserfall".

Another balance for measuring transverse moments which is likewise situated entirely in the modeland indicates the moments values outside electrically has been completed and is ready for use. It likewise serves for stability measurements as those named under c).

The other wind tunnels in Germany to their knowledge possess no balances built in their models.

e) Examination of the Influence of the exhaust flow of rocket units.

Some high speed aircraft or projectiles are jet propelled. The influence of this can be very considerable on aerodynamics, especially on the boundary layer, the drag and stability. At the WVA experimental methods were worked out, which afforded a resolution of this influence and could be applied at any time to fresh problems. For this purpose a battery high pressure chamber and a corresponding high pressure compressor is at their disposal. Corresponding theoretical tests support the actual experimental results.

f) High Tension radio Installation.

For special tests a high tension radio installation is available. With the aid of this rapid photographic exposure of non-stationary processes (e.g. burble paths) were conducted.

With this apparatus explosive waves can be produced, with the help of which field of flow can be scanned and closely determined. Owing to the move to Kochel this apparatus has not yet been put into operation. Upon construction of a suitable room it could be put into use.

No other supersonic wind tunnel in Germany has at its disposal such a high tension radio installation.

D. Survey of the Efficiency of the Other Supersonic Wind Tunnels in Germany.

A survey of the other supersonic wind tunnels in existence in Germany gives the following picture:

A tunnel is situated in Gottingen with flow section 11cm x 13 cm for continuous operation up to Mach number 3.15. Until 1943 there was a supersonic tunnel of 10cm x 10cm, up to Mach No. 3 situated in Aachen. A 20cm x 20cm tunnel was used only in the subsonic region. In 1943/44 the installations were moved to Sonthofen/Allgau and at the end of 1944 were not ready for operation. The supersonic wind tunnel at Gottingen as well as the one at Aachen have a single-stage air drying apparatus at their disposal, so that an increase of the Mach number is hardly possible. Both tunnels possess good three component balances. The smallness of the tunnels naturally only permits the testing of correspondingly small models (namely approx. 8-10 cm long at Aachen and 10-13 cm long at Gottingen), so that fundamentally only three component measurements can be conducted. The execution of far-reaching tests, e.g. detailed pressure distribution measurements, temperature and heat transfer measurements in their distribution of the model's surfaces, stability measurements on oscillating models or built-in balances, measurements on separate stabilizing surfaces, examination of the hinge moments (Scharniermoments) of air rudders, measurements, of rotating projectiles are almost impossible on account of the smallness of the models.

At Brunswick-Volkenrode there are two supersonic wind tunnels. The older one has been in operation since 1938/39. It comprises a machine installation of approximately 800 kW and a measuring section of 40 cm x 40 cm. flow section for continuous operation with a vacuum chamber of 1000 m^3, and thus corresponds to the large measuring section of the HVA. Besides this it has a measuring section of 25 cm x 25 cm with continuous operation.

Both measuring sections can reach Mach No. 3, although there are no nozzles for exact parallel flow, which are the basis of unrestricted measurements of models. As there is no air drying installation no unrestricted nozzles can be produced. Neither tunnel possesses three-component balances so that drag, lift and turning moments cannot be measured. Both measuring sections were used for a long time for carrying out model tests for the construction of larger apparatus.

The newer large supersonic wind-tunnel at Brunswick-Volkenrode has been in operation since the end of 1943. It consists of a blower apparatus of 9000 kW capacity, with the help of which either a subsonic wind tunnel of 100 cm diameter up to the speed of sound can be operated or a supersonic tunnel with flow section 90 cm x 90 cm up to Mach No. 1.5. First line measurements have been conducted up to now in the subsonic tunnel. There were no exact supersonic nozzles in the supersonic wind tunnel for generating an unrestricted air flow and no three component balance to carry out force measurements. The type of blower permitted no increase of the Mach number above 1.5, so that both tunnels of the newer installation are only suitable for research in the region of the speed of sound.

E. Increasing the Efficiency of the Supersonic Wind Tunnel of the WVA by Extending the Machine Installations.

The supersonic wind tunnels of the WVA described in Sections A, B and C could be considerably increased in efficiency by extending the existing machine installations. With this it is possible to transform the existing continuous test operations for high Mach numbers into a stationary operation. This extension has already been technically planned. The second machine house necessary for this could not be erected during the last months on account of the building difficulties. The extension provides for 3 radial compressors, the largest of which has a suction capacity of 150,000 m^3/h and a supply capacity of 5 kg/sec. The total electric power capacity amounts to 21 kW.

The two largest compressors with electric engines and power are already situated at Kochel, the smallest cannot be used and is presently at Gottingen. Compressors and engines have already been acquired. The coast for construction and mechanical apparata would amount to about 400,000 RM. The construction of the machine house could be completed in three months.

With the extended machine installation the evacuation time of both chambers, i.e. the intervals between two tests, could be considerable reduced, while the duration of each separate test could be considerably increased, e.g. with a Mach number of 2.9 the evacuation can be reduced from 5.7 to 1.2 minutes and the duration of the test increased from 38 seconds to 88 seconds. With small Mach Nos. the gains are less, with higher Mach Nos. the gains are greater. Above Mach No. 3.9 the measuring section of 40 cm x 40 cm flow section is carried out with a lastings stationary operation. This represents an increase in efficiency for the WVA of considerable importance.

SECTION XI

GENERAL REPORT ON KOCHEL

WIND TUNNEL WORK

General Survey of Research on the Development of optimum aerodynamic shapes of bodies with subsonic and supersonic speeds.

- -

1. Rocket propelled missiles.

   A. Rockets fin stabilised without wings.

   B. Wing borne and fin stabilized rockets.

   C. Influence of the jet on the aerodynamics of the missiles.

   D. Spin stabilized rockets.

      a) launched from launchers
      b) launched from guns.

2. Projectiles (without rocket propulsion)

   A. Fin stabilized

      a) Developments Peenemunder Pfeilgeschosse.
      b) Further developments of "Pfeilgeschosse"

   (The projectiles of the group II aa have the abbreviation PPG - Peenemunder Pfeilgeschosse).

   B. Spin stabilized conventional projectiles.

      a) Conventional projectiles.
      b) Undercaliber projectiles (sub-caliber)

3. Additional Notes.

   A. Rheintochter
   B. A 10
   C. Taumeln
   D. Hochdruckpumpe
   E. Abstract of report on the 38 cm rocket assisted shell.
   F. Report on possibility of cooling hot gases from rocket jets.
   G. Recent work of the WVA
   H. Photo-electric proximity fuze development at Kochel.

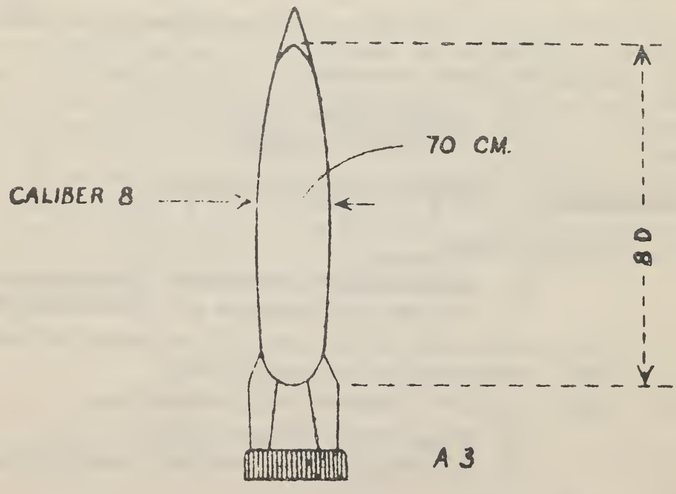
I. Rocket propelled missiles.

A) Rockets without wings which are stabilised by arrow surfaces.

Examples: A_3, A_5, A_4 (alias V2); A_9; Taifun; Puppchen as forerunner of the Panzerschreck, Panzerfaust:

a). A_3, A_5, A_4.

A_3, A_5 have the infantry bullet as the basic prototype. In 1936 A_3 was measured in Aachen. Problem was to stabilise a body of 8 calibres with nose of smallest resistance and Ma = 0 to 2.3. In addition the device must be "programmatically" steered through built in controls. A_3 was fired 4 times to about 400 meters height and furnished the first evidence that missiles could be aerodynamically stabilised by solid fins. Previously rockets were generally somersaulting all over the place.



A 3

Thrust = 1500 kg, Duration ca 45 sec. Propellants: LO + Ethanol + H_2O.
A_3 was intended to be stable subsonically and supersonically. (In professional circles the prejudice that fin stabilisation supersonically is not possible). No reports are available on A_3, but all the results on A_3 have now been superseded. (Characteristics F = 1500 kg, total weight 750 kg, vertical acceleration 1g). The control device in the A_3 was not quite sufficient and the A_5 was therefore started with better "Leitwerk" = manifold of the fins, improved "Steuermaschine" = control-steering manifold and compensation of the spin which has its origin in the imperfections of the construction and the higher order (quadrupole) torques due to lateral wind.

b) $\underline{A_5}$.

Thrust, weight, body are about the same as for A_3 (perhaps D = 80 cm instead of 70 cm). In the summer of 1938 the first models were launched without gyro-electric-hydraulic steering (navigating) machine. In October 1939 the first models with the robot pilots were launched. (20 to 30 tests in the year 1939 - 1941). The models were recovered with double parachutes. Vertical ceiling 7 km, range 15 km. All of the flight paths were stable and reached maximum speed of 300 m/sec. in the transsonic region.

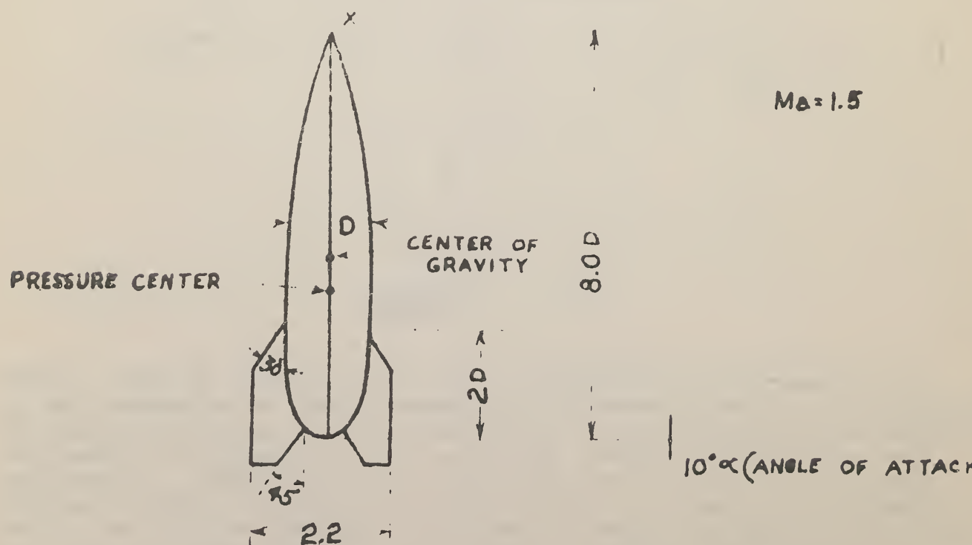
Intended was A_6 with $F \leq 8$ tons, but [illegible] never came about.
A_6 was to be the first guided missile with speeds greater than that of sound.

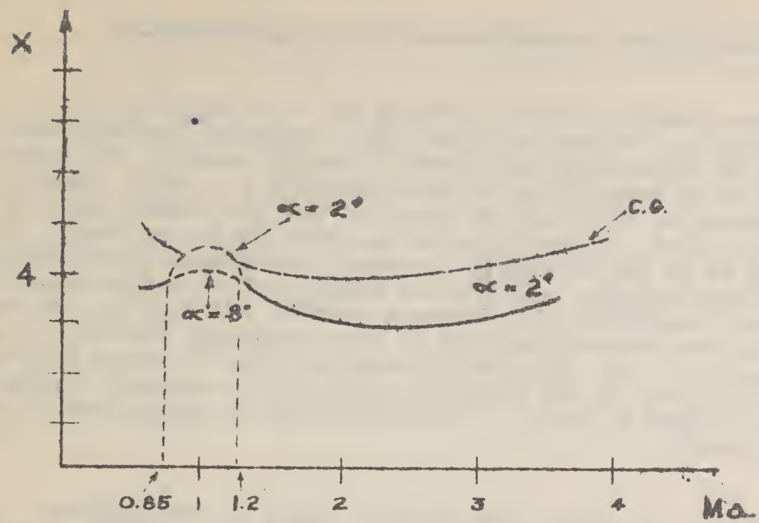
c) A_4 (alias V2)

Was tested in flight for the first time in June 1942 in presence of Reichsminister Speer. Explosion of combustion chamber occurred at several meters height. October 3, 1942, the first successful flight was made by an A_4 over a range of 250 km. Everything worked well including combustion, controls, stability etc.

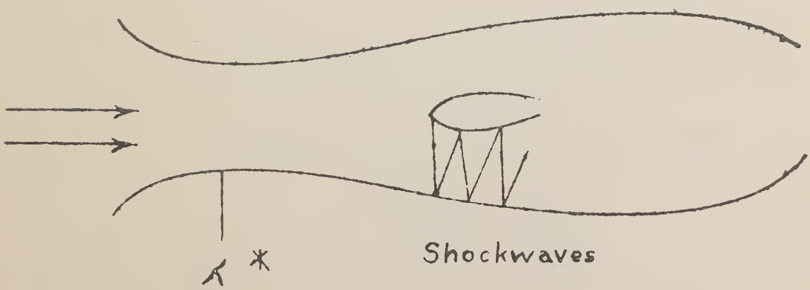
1) The wind tunnel had as its main problem the construction and testing of solid stabilizing fins and at the tail of the fins small aerodynamic rudders.

The distance of the pressure center, which for stable flight is [illegible] the center of gravity, is 0.3 calibers from the center of gravity.





Mach numbers Ma ~ 1 cannot be used in the wind tunnel because the head shock wave of the model gets reflected as shock waves either on the solid walls of the tunnel or as rarefaction waves on the interface between the flow and the surrounding air.



Near Ma = 1 the pressure centers come dangerously near the CG. To make sure that nothing would happen at Ma = 1 with the A_4 similar bodies were dropped from planes from 8000 meters height and observed in their transition through Ma = 1 at about 1000 meters altitude. A_4 flow up to Ma = 5 at a point which coincided closely with "Brennschluß" = propellant cut-off.

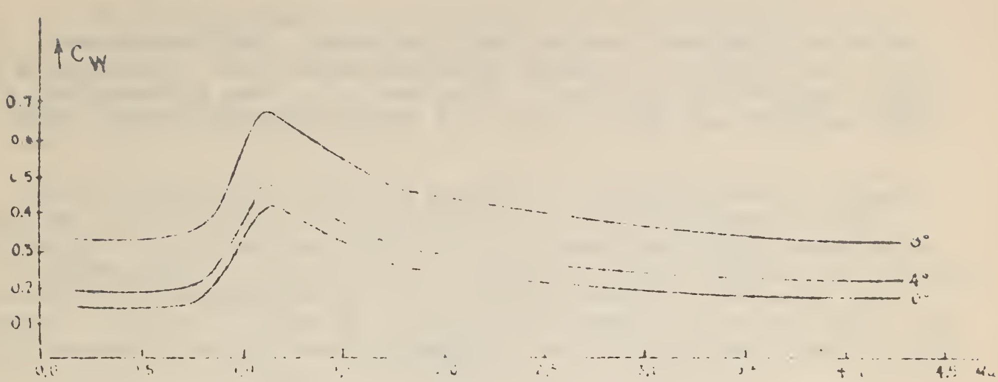
Basic aerodynamic problem of stabilization of the guided missiles
- -

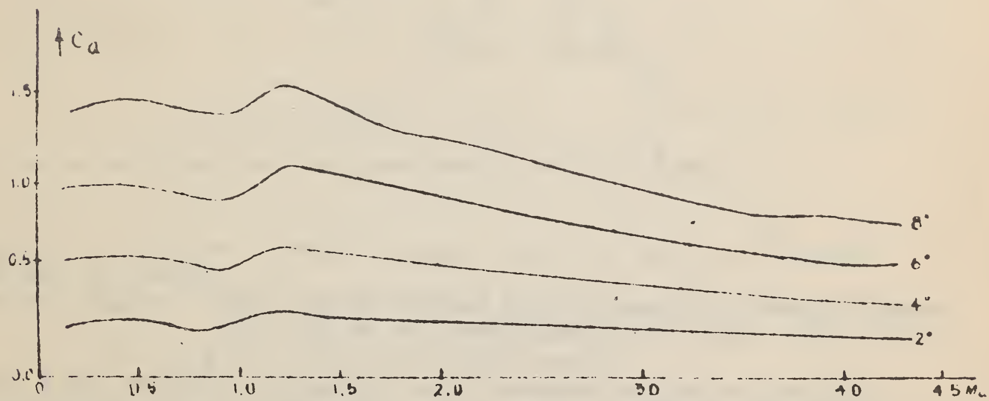
The difference between the CG and the CP has to be positive (stability) but Δ = CG - CP has to be very small otherwise the projectile has the tendency to fly straight and cannot be easily steered, the steering torque necessary being proportional to the distance Δ = CG - CP. When Δ is small the rudders can be small and the power to turn the rudders small so that much weight can be saved. The Δ 's are in the order of 0,3 calibers. The two curves CP and CG as function of Ma (or time, or distance travelled) had to be determined very exactly. Geometrical changes had to be introduced in order to make Δ as constant as possible as a function of a and Ma. The change of Δ with a and Ma was markedly improved as work progressed from the A_5 to the A_4 to the "Wasserfall". For "Wasserfall" they succeeded to reduce Δ to within the limits of 0,2 caliber in the range from subsonic to supersonic speeds and angles of attack between 2^o and 8^o. "The CP for smaller angles than 2^o cannot very well be measured).

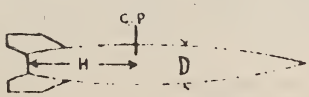
(In the A_4 steering is entirely accomplished by means of the graphite plate rudders in the jet, which cease operation at "Brennschluss" = propellant cut off. The rudders on the fins are intended only for spin stabilization = "Drallsteuerung")

(2) Determination of drag and lift of the A_4

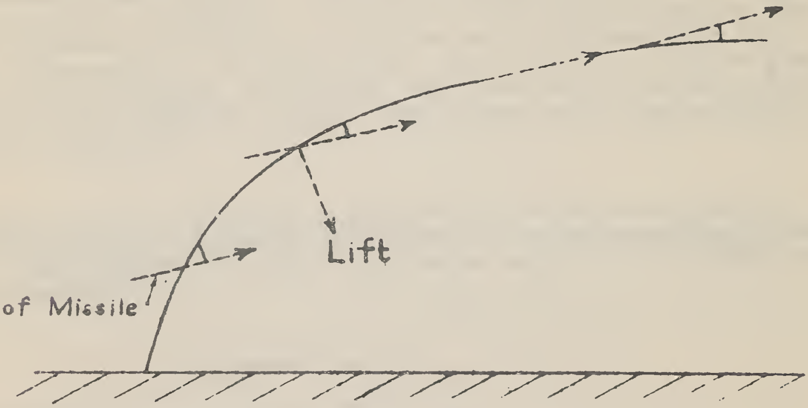
The drag and lift coefficients look as follows:







[illegible] is very essential for the range while c_L is essential for the curvature of the initial curvature of the orbit. (See the diagram). The greater the curvature required, the greater must be the "lift" (acting to the right downward) on the missile. Therefore in the case of Wasserfall, where large curvature are required, the lift must be generated through actual wings.



About 16 models with considerable variations were tried. Actually the one of the first models was actually used for the $V_2 = A_4$.

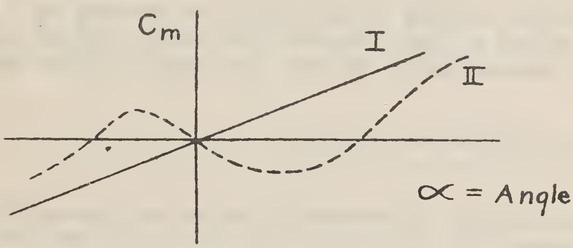
(Maximum stagnation pressure at the beginning of the dive was 6 ata).

The "Gleitzahl". C_L / C_D

The ratio of CL/ CD (lift-drag ratio) follows from the above curves and is applied for the calculation of the path.

(3) Spin control with air rudders.

It was determined in the wind tunnel which rolling Moments (Torques) originate in the asymmetries of construction and in the lateral winds. Instrustions were given the constfuction engineers how large inaccuracies of the line up of the fins could be tolerated. A "Tast Maschine" = automatic deviation measuring machine was built which automatically accepted or rejected the bodies for the A_4. Subsequently rudders had to be built which could compensate positive moments with the small torques which the steering machine was able to manage.

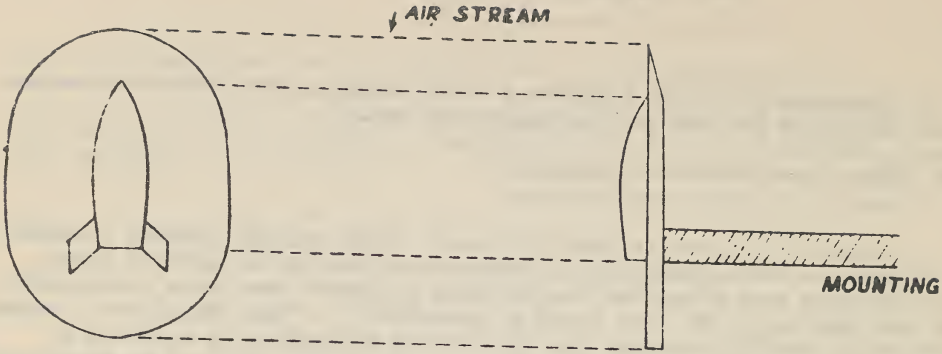


Only C_m's of the type I could be managed, both for the c_m of the main body and the rudders.

($M = c_m \frac{p}{2} V^2$ is the pitching moment)

C_m had to be plotted as a function of a for all significant Mach numbers. (Only in the Wasserfall were tolerated and compensated for the first time negative $\frac{dc_r}{d\xi}$ where c_r is the moment coefficient of the rudder and ξ the angle of rotations (nobody has as yet managed to control negative $\frac{dc_m}{da}$ s.

The moments of the rudders could be relatively easily measured in the supersonic region by halving the model and limiting the air stream by a plate (see sketch) which made it possible to lead out with rods which transmitted the turning moments of the rudders to measuring dials.



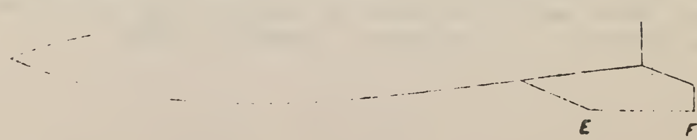
For subsonic flow the halving of the model and backing by a flat plate does not work. Models of the bisected type shown were of course used only for pressure measurements and not for drag, lift and moments.

(4) Pressure distribution over the A_4.

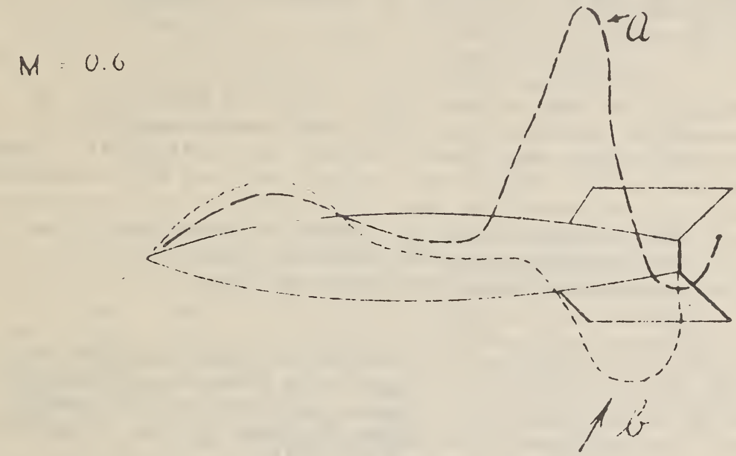
This pressure had to be measured in order to furnish the basic data for the stress analysis to be used in the choice of the static structure of the A_4.

About 120 fine drill holes were used on the model. All connected with small hoses to 120 manometers.

Since pressures for 9 velocities, sixteen angles of attack from -8^o to $+8^o$ were measured four to five times each, a sumtotal of about 120 000 data on the pressure distribution was obtained. (For results see special reports and also "Geschosse ohne Drall" 1943, Heft 1059/43 of the Deutsche Luftfahrtakademie.) Watch the very interesting pressure distribution over the sharp edge E on the rudder, which changes



radically from the subsonic (relatively large pressure over E) to the supersonic flow (about equal pressure over E and F). The CP was shifted forward with increasing Mach number in agreement with the diagram on page).



a) Integrated pressure distribution, (or normal forces on the axis) on fin stabilized projectile.

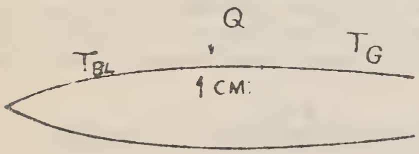
b) Same distribution on missile without fins, which clearly demonstrates that the finless missile is unstable.

Pressure distribution on the rudder.

See report 152 on rudders and No. 171 on Wasserfall.

(5) Skintemperature of the A_4. (No. 4, 5, 14 special reports).

At first in 1938 the temperatures were determined theoretically. With the wind tunnel in operation after 1939 exact measurements were started (especially from Spring 1940 when the air dryers were installed). Report 57 contains the experimental data on wind tunnel tests of skin temperatures. Cone shaped bodies of various angles were introduced, as well as spheres, discs and so on. Heat transfers were determined in dependence of Ma. (See also Vol IV. of the Handbuch der Experimentalphysik, Busemann, p. 443). (No integral energy-radiation balance was made for the A_4).



Problem: To determine the heat Q which is transferred from the gas to the body per cm^2 second. Secondly: What is the temperature of the skin?

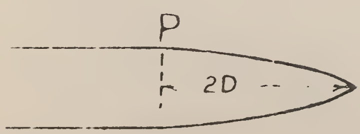
T_G = $T_{Grenzschicht}$ = boundary layer
T_{Bl} = Blechtemperatur = skin temperature.

If a = heat transfer per second and cm^2 at a given point P at a distance from the leading edge and λ is the heat conductivity, then Nusselt's number

$$Nu = f\ (Ma, R) = \frac{\alpha d}{\lambda}$$

as a function of Mach number Ma and Reynold's number was plotted.

After the above curves were established the skin temperatures were calculated for the whole orbit. (Only one point P on the skin was calculated, where the temperature was estimated to be the highest).



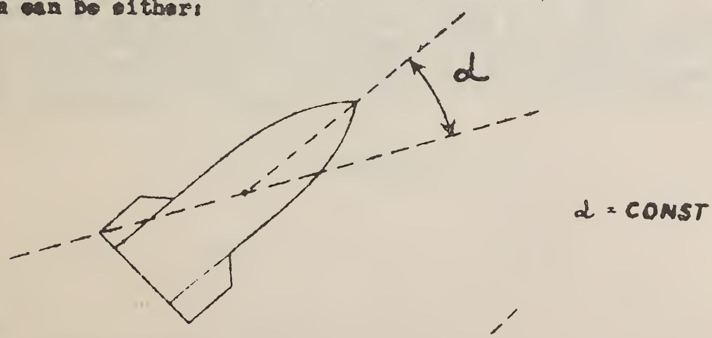
The same procedure was applied to different types of orbits and different types of bodies.

d) **Taifun.**

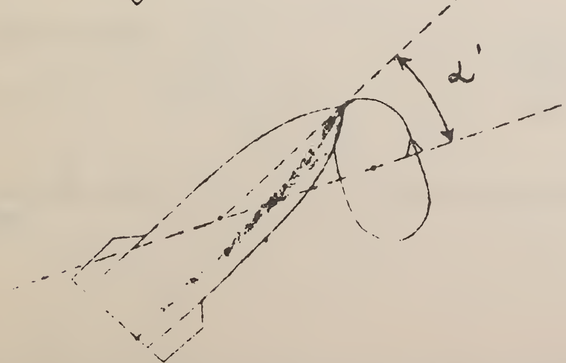
L = 180 cm, D = cm. Problem was to find fin manifold not longer than the combustion chamber (this purely for convenience of mechanical assembly) Stability up to M = 3, 6 was required. In addition tumbling (which sets in when the spin frequency and the frequency of pitch motion or yaw motion are equal) must be eliminated. Solution: Fins are intentionally shaped so as to make the spin frequency ten times that of the frequency of the oscillation about the two short (symmetrical) axes of the ellipsoid of inertia. The problem was not really brought to a successful conclusion.

e) Puppchen.

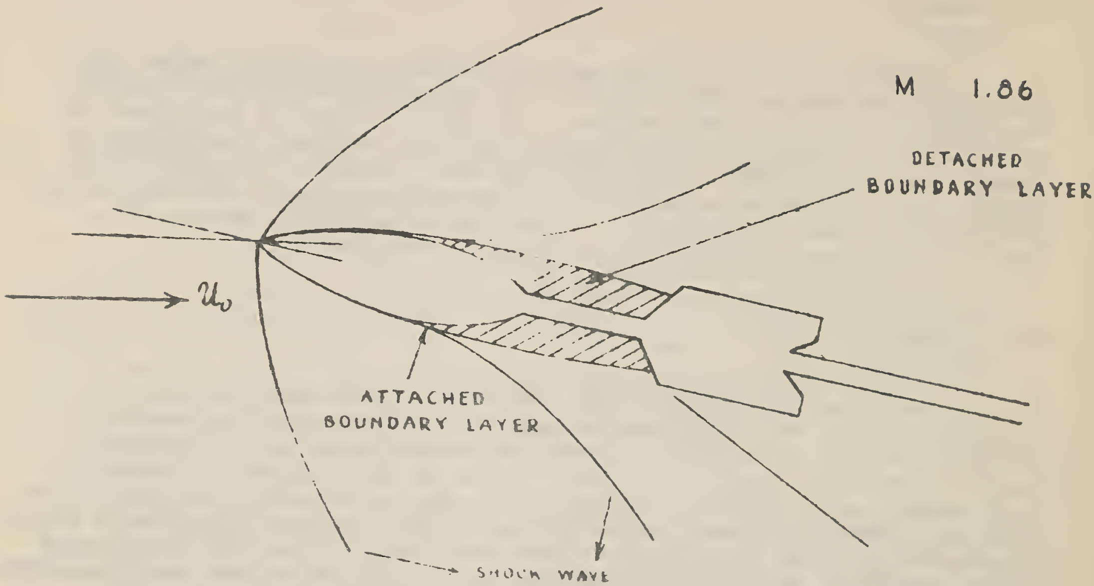
As forerunner to Panzerschreck. Original caliber was 5 cm; was increased later. The wind tunnel worked essentially on the fin manifold (= Leitwerk) for the stabilization of the missile which had an intended range of 200 m and speed of 250 m/sec. (Used by the infantry and launched from smooth tubes). The development of Puppchen was attempted for supersonic speed which would have been reached if the missile had been fired from a plane. This development was not finished. Basic difficulty is that the fins cannot extend beyond the body as it is possible with rockets which are freely launched. In spite of the fact that a dozen shapes were tried none was found which remained under equilibrium angles of attack of about 8°.
Motion can be either:



or

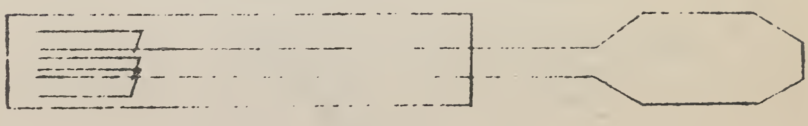


Interference of the boundary layer with the fins is disturbing especially when there is a finite angle of attack as the sketch shows.



Panzerschreck which is the finished product based on the Puppchen was fired from a tube, while the similar Panzerfaust was fired from a sleeve. (The fins of the Panzerfaust were folded into an Umbrella). Sleeve was held by the operator.

Panzerfaust



B. Wing born and arrow (fin) stabilized rockets.

a) Wasserfall.

First wing born missile to fly stably with subsonic, transsonic and supersonic speeds up to $M \sim 2,5$. (Was actually intended for $M = 3$.) Four wings were necessary in order to allow manoevering of the Wasserfall in all directions and positions. At first wings and fins were 45° out of phase because it was thought that in this way the immersion of the rudders in the trailing Vortex Street could be avoided. This proved to be wrong for large angles of attack for which the arrangement of wings and fins identical in span, shoulder angle and total surface area was shown to be more advantageous. Subsonically 15° angle of attack was necessary while supersonically 8° was required. The main difference between A_4 and Wasserfall is for Wasserfall a Δ = CG - CP (zero point at the nozzle (Heck)) was achieved which as a function of Ma is almost constant from 0 to 2,5. $\Delta \sim 0,3$ im Mittelwert. The final shaped for the Wasserfall was based on the experiences gained with 24 models which were tested in the wind tunnel.

C_D and C_L were measured as a function of Mach's number for both positions where the wings lie in and normal to the plane of tangent to orbit and axis of missile and the case where the wings subtend angles of 45° to this plane. Surprisingly C_D and C_L for both positions were almost the same.

The lift coefficient for the Wasserfall is about 50% larger than that of the A_4. The C_D's are also about in the same proportion. Consequently the drag-lift ratio is about the same for the A_4 and the Wasserfall. The latter therefore is no better glider than the A_4, but because of its higher C_L is manoeverable in sharper curves.

$$A_4 \text{ without fins} \quad \frac{dc_L}{d\alpha} = 3.0$$

$$A_4 \text{ with fins} \quad \frac{dc_L}{d\alpha} = 10,0$$

α is defined in radians.

$$c_L = \frac{\text{Lift}}{S \cdot p_s}$$

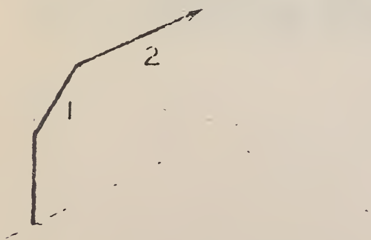
where $p_s = \rho v^2/2$ and $S = \pi D^2/4$ with these data about 30 rudders were tried and calculated.

η = rudder angle.

Plotted was α against η in order to get an idea of the actions of the rudder control on the angle of attack α of the missiles (for torque free positions of the missile). All curves are plotted with the Mach number as a parameter. With increasing Mach number ($M = 0{,}6 \rightarrow 2{,}9$) the angle α for given η drops by about 60%. Controllability of the missile with increasing Mach number therefore decreases. With $\eta = 15°$ the required maximum α of $15°$ for subsonic speed and $8°$ for supersonic speed can just be achieved.

For the crossed position of the wings and fins X the curves $\alpha(\eta)$ become such as to allow in some cases two values of α for a given η which means that there is also a point $\frac{d\eta}{d\alpha} = 0$ of instability through which the missile may be thrown from the first α to the second α. Problem was to shape the fins and wings so that the point of instability would fall outside of the military required range of angles.

Aerodynamically the vertical paths and the longest paths were analyzed. Device was ultimately guided in two directions. (1, 2)



Flow through the critical region to supersonic speed without any difficulty.

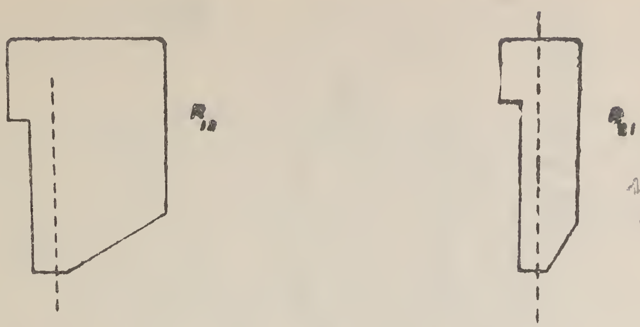
Requirements for the rudders:

α) with $25°$ excursion of the rudder an excursion of the body must result of $15°$ at subsonic speed and $8°$ at supersonic speed.

β) total normal integrated force had to be less than one metric ton (otherwise construction would have been too heavy).

γ) Δ $2°$ deflection of the four rudders in "swastica" configuration must compensate for all spins originating in the asymmetry of construction and lateral wind. Final shapes adopted were R_{12},

R_{21} (rudder 21), depending on the capacity of the rudder machine,



R_{21} has 75% of the surface of R_{12}. For detailed discussion of the hinge moments on the rudders see Wegener's report No. 165.

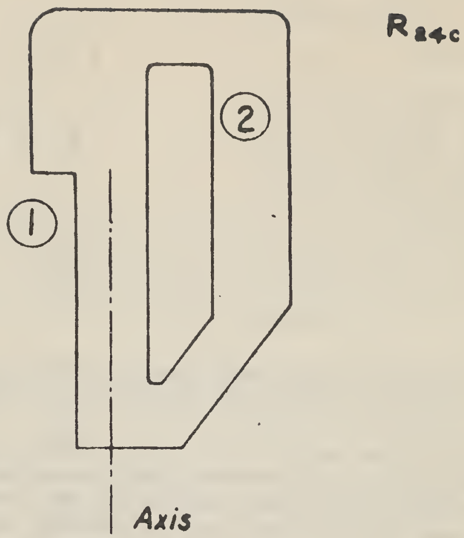
Further development was tried with double rudders (according to the Flettner idea) to reduce the hinge moments as far as possible. First was tried to only fix the auxiliary rudder while the main rudder followed freely. It turned out that excursions of the auxiliary rudder influenced the main rudder less and less as the forward speed increased, so that this type of rudder is not promising. The requirement of stability in the subsonic region makes the rudder too stable in the supersonic range.

Second attempt was to have auxiliary rudder and main rudder coupled (η_1/η_2 = const.). (This was in the first development stage).

$$\underset{\text{(of rudder)}}{\text{Torque}} = C_R \frac{\rho}{2} U_0^2 \; S \; . \; D.$$

One must try to avoid negative $\frac{dc_a}{d\eta}$. In order to conveniently compare the different rudders the numerical values of S and D are taken as those of the projectile rather than as those of the rudders (as it is done in the aerodynamics of airplanes).

The final solution seemed to be indicated by a perforated rudder of the following type (about the same size as R_{12} and one caliber long).



The pressure peak at (1) is presumably counter balanced (in its effect on the torque around the axis) by a new pressure peak at (2).

Skintemperature of Wasserfall is 180°C while the boundary layer gets to 220°C.

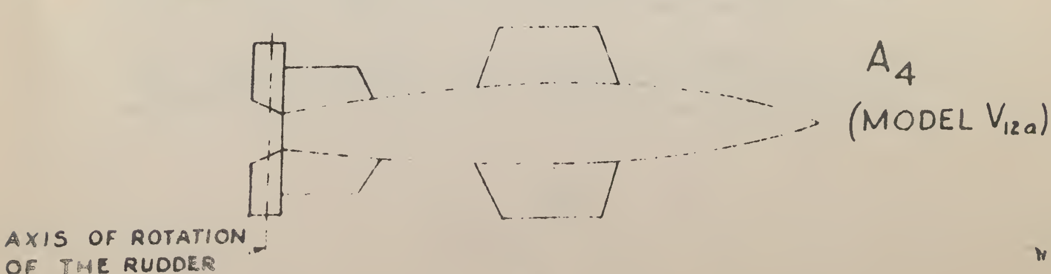
b) <u>Development of R-Drachen.</u>

Rocket from plane to plane and 500 m/sec. $D \sim 21$ cm $L = 10$ D. Similar to Wasserfall, except for two wings instead of four. Was analyzed only theoretically before it actually flew. Was not actually used.

c) <u>Forerunners of A_9, and A_{10}.</u>

a) Glider A_4 (Fin projectile A_4 = "Flossengeschoß A_4).

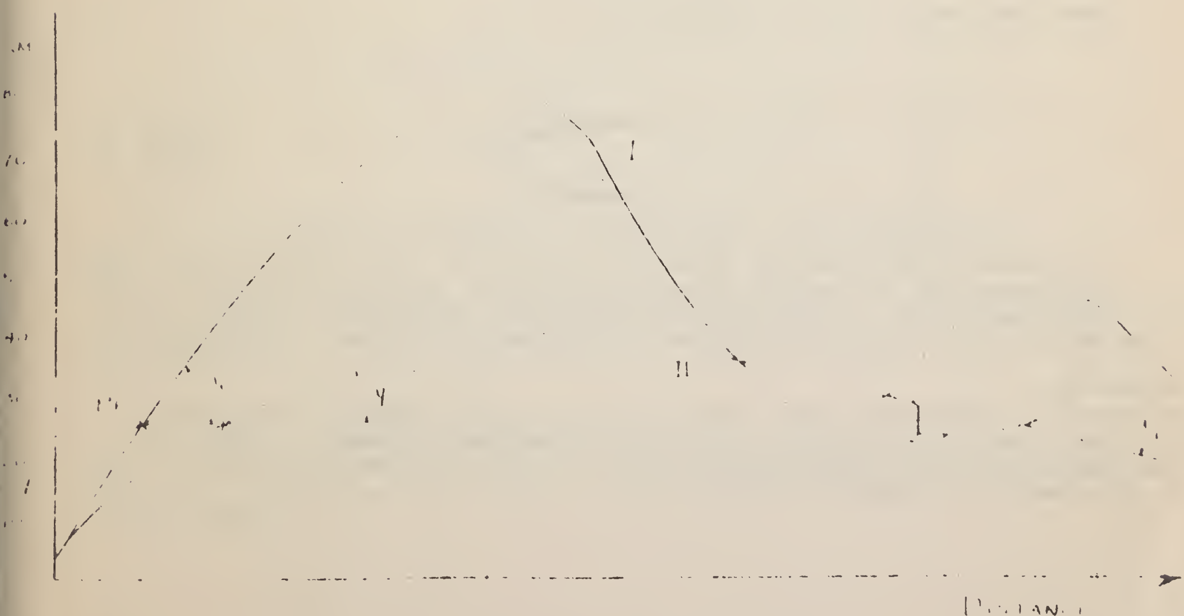
Development started 1940. The program was to take the body of A_4 as it was and to attach wings for the purpose of increasing the range from 270 km to 450 km. Total weight of propellants and of the warhead were to remain the same as for A_4. The following basic designs were investigated



From the analysis of the families of orbits the following results were obtained.

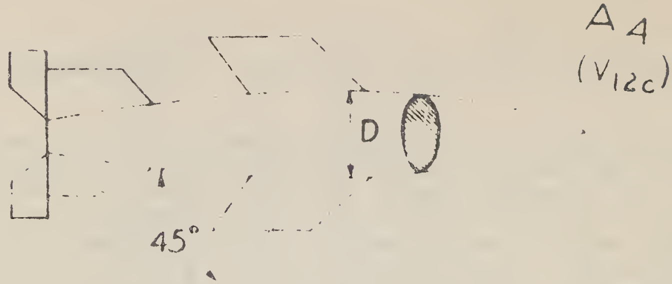
If one launches the missile (orbit I in sketch) vertically up to "Brennschluß" = propellant cut-off and transforms all of the available chemical energy into potential energy, the missile flies to a peak (about 30 km) at which the density of the air is too small to support gliding. The missile therefore falls rapidly and the orbit oscillates without achieving a large range. All other initial angles Ψ at Brennschluss were also assumed and the resulting orbits analysed. It was found that an orbit reaching a ceiling of 40 km was most advantageous and theoretically gave a range of 450 - 500 km. The original calculations were all made with assumed lift-drag ratio (~ 6 for subsonic flow and ~ 4 for supersonic flow). Orbit II in sketch schematically illustrates the best conditions. This orbit was calculated with lift-drag ratios actually determined in the wind tunnel.

(A4 incorporated the first design for supersonic air foil sections and the first wind tunnel tests on such sections, while Wasserfall was the first object to fly through the critical velocity region with wings).



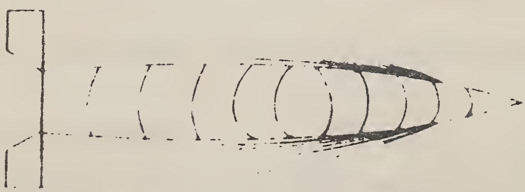
x = Brennschluss = propellant cut-off

Various shapes of the wings were as follows:



V_{12c} was superior to A_4 (V_{12a}) because of higher Lift-Drag ratio. The total area of the wings was about $6.34\pi D^2/4$ which is about the double area of the [illegible]. (A_4 has two wings and four fins). The improvement of V_{12c} over V_{12a} was about 10% or 40 km additional range. V_{12a} was the best model as far as lift drag ratio is concerned but was bad because the center of pressure moved back more than one D from the subsonic flow to the supersonic flow. In order to allow the steering mechanism to control the large lever arm and torque at supersonic speeds it was intended to place the CP slightly in front of CG for subsonic speed.

Next model (Sept. 41) of A_4 was a V_{12a}.



The total wing surface plus the fins was $8.18\ D^2/4$. (For the V_{12c} we had $6.34\ \frac{\pi}{4} D^2$ for the wings and $1.06\ \frac{\pi}{4} D^2$ for the fins which also contribute to the lift).
This model is all round bad and cannot be used since it is characterized by poor lift-drag ratio and large motion of the CP with Mach number. C_L/C_D is 20% lower than for the V_{12c}. (Motion of CP from small to large M's is 2% greater than for the V_{12c}).

V_{14f} is a little worse than V_{12c} as regard lift-drag ratio.
(=5,6 subsonic, = 3,6 supersonic).

The position of the CP was less dependent on Mach Number.

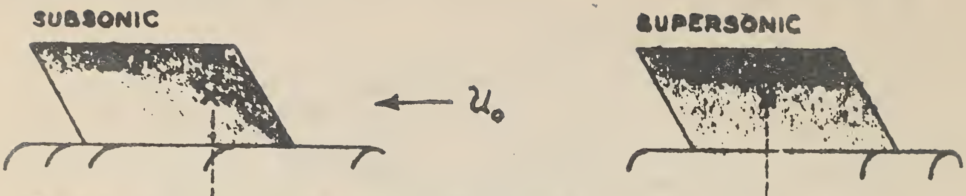
A_4 V_{14g} and A_4 V_{14h} were similar to V_{14f}, with larger wings which did not improve the lift-drag ratio. (1½ year intermission).

$A_9 = A_{4b}$.

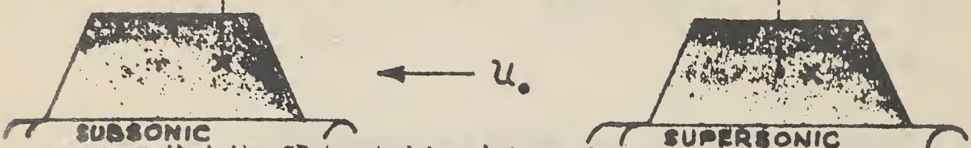
A_4 V_{12c} was taken as the basis to start from. The problem was to leave the lift-drag ratio as it was but to avoid the movement of the CP. For this (after 1½ years of work) the experiences gathered in the development of Wasserfall were available. The CP had to have as fixed a location as possible and CG - CP had to be less than a certain amount given by the following requirement:

For $\eta_{max} = 25^\circ$ (rudder angle) ⟶ a = 8° in the supersonic region.

Like in Wasserfall the fixing of the CP was accomplished by trapezoid shape of the wing. In general the highest pressures are distributed as follows (shaded areas):



Therefore if the following change is made:



one sees that the CP (marked by x) is moving forward only for the supersonic flow which makes for less dependence of the location of CP on M. Nevertheless CP (subsonic) - CP (supersonic) $\cong$ 0,6 D which is a little too much. Lift-drag ratio was 6 and 4 respectively subsonically and supersonically (No change as compared with V_{12c}). Was intended to reduce the 0,6 D to 0.2 D, but the rudder machine could handle 0.6 D motion. About 14 intermediate shapes were tried.

$A4/F_4/L_1/R_3$ (F = Flügel, L = Leitwerk, R = Ruder, A - Aggregat)

should have been the final form. For this it was
CP (subsonic) - CP (supersonic) = 0,4 ⟶ 0,6 respectively for $a = 15^o \to 0^o$. Since the wings in this model are smaller than in the V_{12c} the lift-drag ration decreased by 10% about and was 4.8 for M = 0,84 and 3,7 for M = 1,89. CG - CP is not yet known because the construction engineers had not furnished the data. For A9 an instability in α of α = 5° would have been tolerated.

For the rudders the same types were used as in Wasserfall except for certain changes in dimension to conform with the different size of the A9.

One device "Bastard" was flown, which was concocted of a regular A_4 plus wings welded on, in order to determine how the wings pass through the region M = 1.

Comparison values of c_D

$A9 \longrightarrow c_D = 0.22$)
) subsonic
$A_4 \longrightarrow c_D = 0,14$) M - 0,6

$A9 \longrightarrow c_D = 0,39$)
) supersonic
$A_4 \longrightarrow c_D = 0,25$) M - 1,86

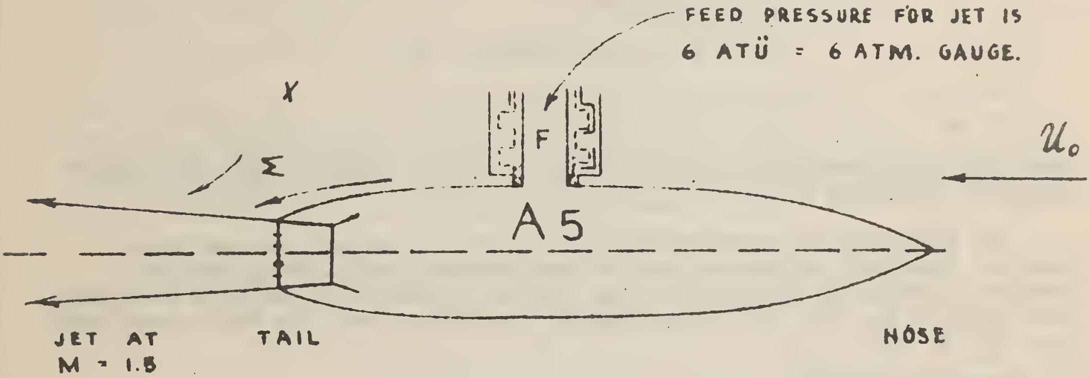
Additional remark:

With large span of the wings it is difficult to keep the CP relatively fixed with changing M. One therefore is forced to adopt small spans and sacrifice some of the "glidability" of the missile.

C. Influence of the jet on the jet on the aerodynamics of the missiles.

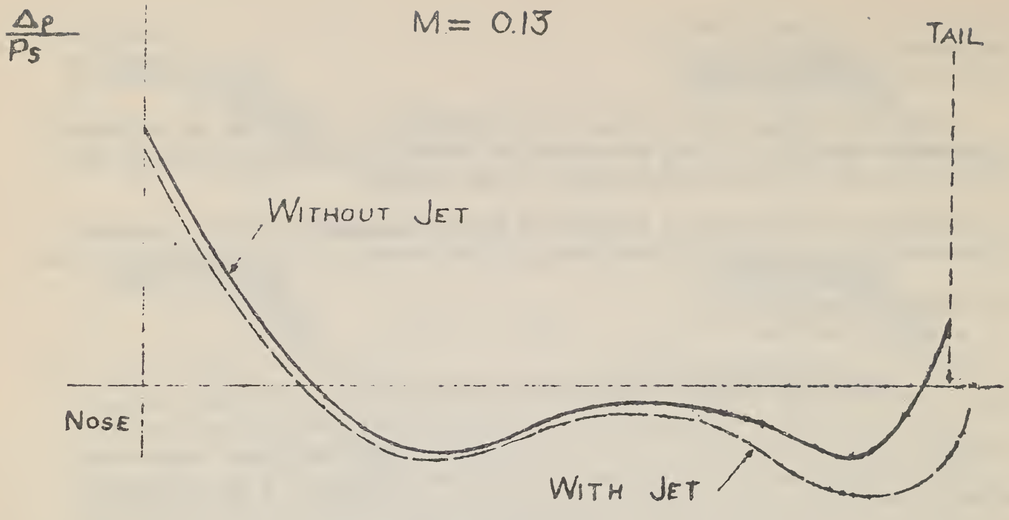
(1) Subsonic region.

Experiments were tried only on models of A_5 and A_9 .



"Labyrinth Dichtung" = Maze leak for the excess air escaping from the feed tube F was used in order to have the model freely movable around a vertical axis.

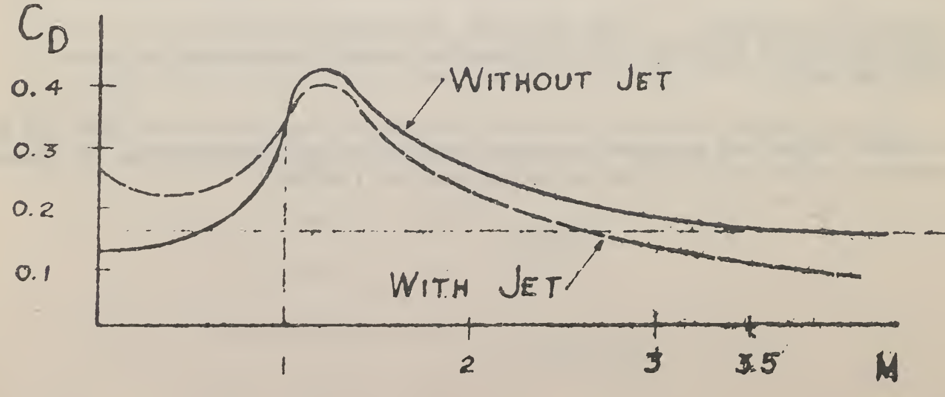
The pressure distribution over the surface was determined with the help of small holes and attached pressure gauges along six meridians. A typical pressure distribution along a meridian is as follows:

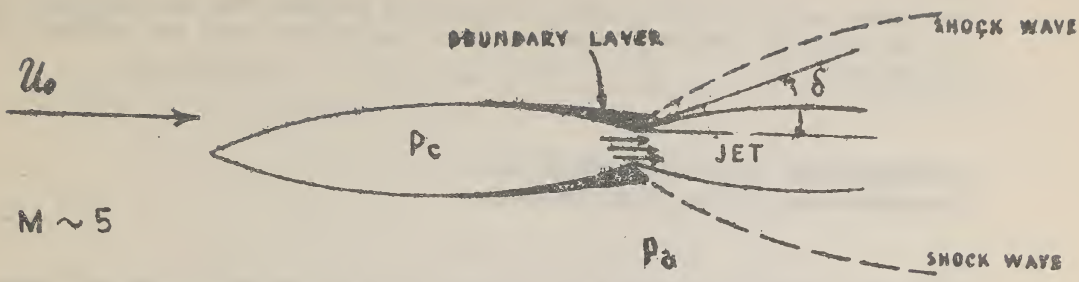


Note the slight positive pressure at the tail (indication of the conditions valid for the ideal flow).

The gases are entrained through the jet with resulting greater under pressure (suction) at the tail end of the immersed body. Since both the positive pressure at the nose and the negative pressure at the tail contribute positively to C_D, the jet which enhances the suction over the tail contributes a $\Delta C_D > 0$

(2) Supersonic region.

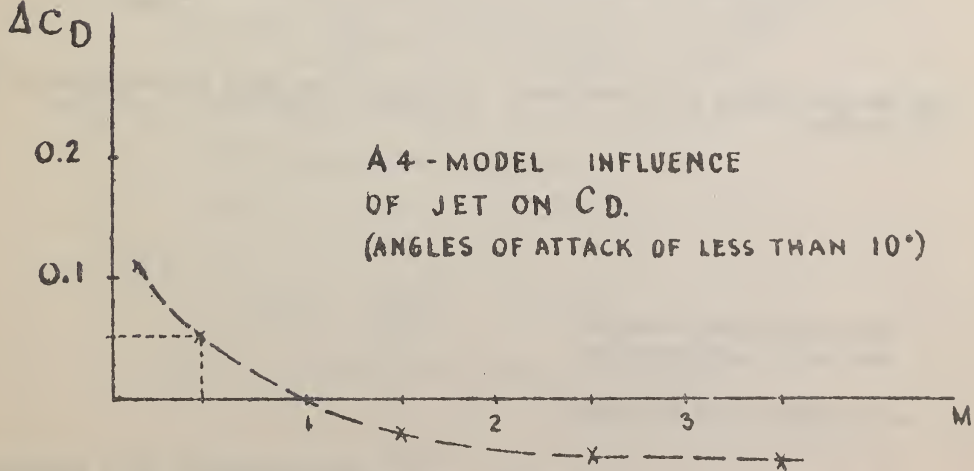




P_o = 4 mm Hg.

$P_c/P_o \sim 60$ corresponding to M = 5,3.

The boundary layer at the tail increases with forward speed. With the jet on it grows thicker yet with the result that higher pressure is built up over the tail section. As the angle of divergence δ of the jet increases with decreasing external pressure, the boundary layer grows and the pressure on the tail increases, resulting in a decrease of C_D of the whole body.

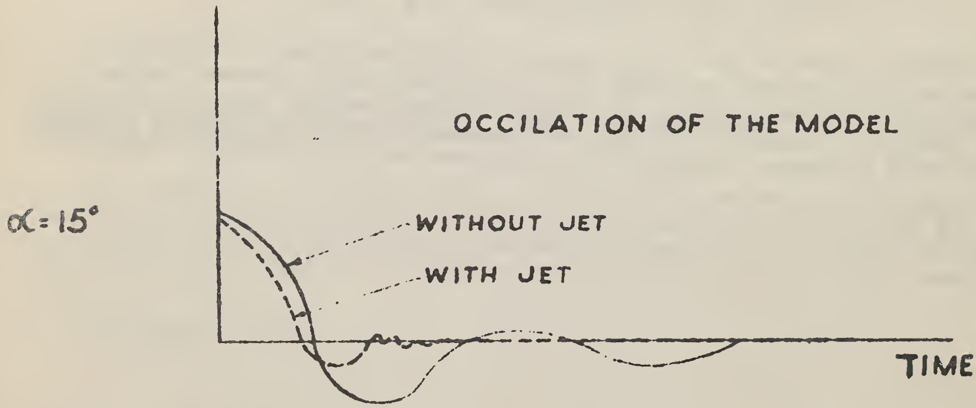


The actual paths of the A_4 were not actually analyzed for the influence of the jet on C_D of the whole missile. Lift coefficient with the jet were not determined.

Investigations of stability with jet.

A_5.

The center of pressure was displaced by 0.5 D towards the tail when the jet was started. The missile consequently becomes more stable (A_5). The increase of stability was checked through observation of the oscillations of the model without jet and with jet.



For the jet only M = 1,5 was used. No other cases were investigated in the wind tunnel.

D. Spin stabilized rockets.

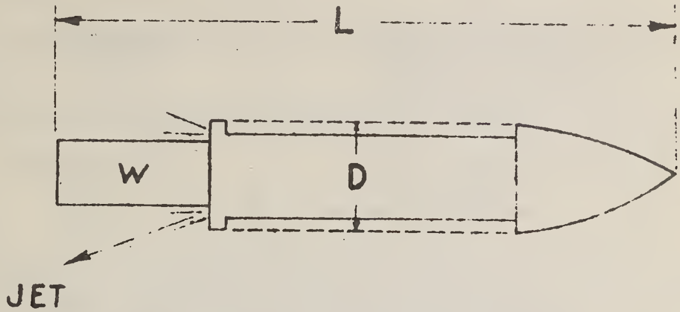
a) Launched from launchers.

To these belong the following rockets, DOV projectile (Do = Dornberger), 15 cm "Wurfgranate", 21 cm "Wurfgranate".

In Germany all of these rockets used solid propellants for their propulsion. (Duration ~ 1 to 2 seconds).

DOI

Wind tunnel investigations of lift, drag and pitching moments were made. D = 15 cm and L = 6 D.



W = warhead ([illegible] at the tail in order to achieve greater fragmentation and destruction of [illegible] near the earth's surface.

Definitation of coefficient of stability σ

$$\delta = \left(\frac{U_p}{U_o}\right)^2 \rho_I \cdot \frac{1}{\rho} C_\sigma$$

where

$$\rho_I = \frac{8}{\pi} \frac{I_e^2}{I_q D^5} = 2.5465 \frac{I_e^2}{I_q D^2}$$

and U_p = peripheral velocity

U_o = the forward speed of the CG

p = density of air

$$C_\sigma = \left\{ \frac{1}{\Delta \left[C_D + \frac{dC_L}{d\alpha} \right]} \right\}_{\alpha = 0}$$

is the "aerodynamischer Stabilitätsbeiwert"

Δ = distance CG - CP

I_q = moment of inertia around a short axis of symmetry.

I_ℓ = moment of intertia around long axis symmetry.

D = caliber

n = number of revolutions of projectile per minute.

From experience in external ballistics it was found that if

$$\sigma \geqq 1.3$$

then the projectile (without fins and wings) flies stably.

If $\sigma < 1{,}3$ then the projectile tumbles or becomes totally unstable. Stability up to M 0,8 is usually relatively easily attainable. Through M 1 the stability is often lost. Actually stability through M = 1 could not be achieved with the designs used so far.

15 cm Wurfgranate.

Was launched out of a smooth tube. D = 15 cm L = 6,5 D. The meaning of all of the work in the wind tunnel was to determine C_L, C_D and Δ as function of M from 0,6 to 1,86 in order to determine from the required inequality $\sigma \lesseqgtr 1{,}3$ the necessary spin for stabilization, where by this spin was to be generated by proper inclination of the jet exhaust nozzles (which were arranged on a ring).

21 cm Wurfgranate 42 L/5, 7.

L = 5,7 D. Rocket was in development was tested in the range $0{,}58 < M < 1{,}86$. Models were 1 : 6 to the full scale projectile. In wind tunnel test C_L, L_D, were determined and again from the requirement $\sigma > 1{,}3$ the necessary spin for stable flight was calculated. Essentially the ratio U_p/U_o = peripheral velocity/forward velocity must be determined and then generated through the inclination of the jets which are arranged on a ring.

The development of the rockets was in the hands of Wa Prüf 11 = Heereswaffenamt - Prüfwesen

3) [illegible] rockets [illegible]

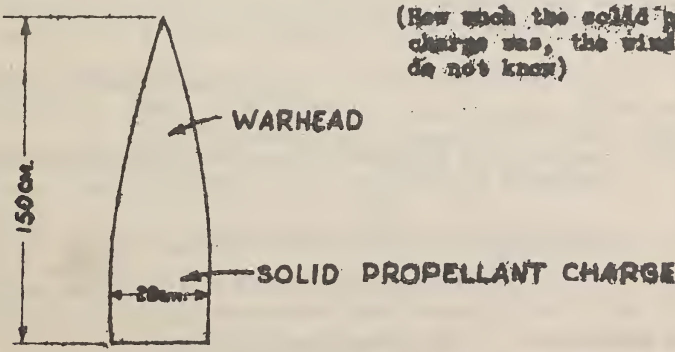
[illegible] the following [illegible]

conventional shells	[illegible] shells with [illegible] rocket propulsion
Sub-caliber shells	Sub-caliber shells with rocket propulsion

Conventional shells with additional rocket propulsion.

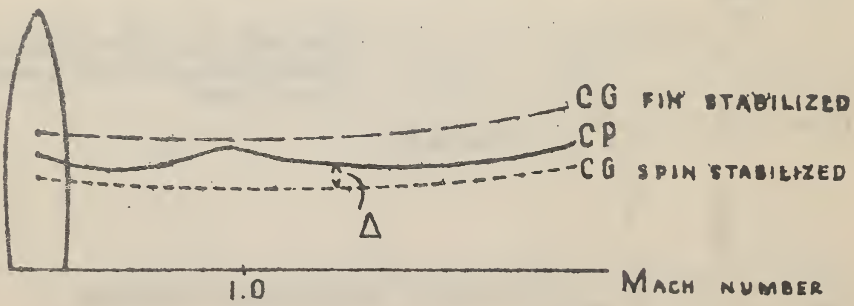
C_D, C_L, Δ were analyzed in the wind tunnel and again [illegible]. Otherwise no work was done on these shells, which had an additional [illegible] propulsion after 10 to 15 seconds flight. Scale of model to prototype is 1 : 8,4.

(How much the solid propellant charge was, the wind tunnel [illegible] do not know)



Example: Caliber 28 cm, L = 5,36 D. Muzzle velocity ~ 1008 m/sec. Maximum after the additional propulsion is not known. Dispersion is very bad, because rocket propulsion is applied in various directions depending on the inclination of the projectile at the moment of ignition.

Maximum range of the 28 cm shell is about 60 km without additional propulsion and 80 km with additional propulsion. This means that the projectile is stable. (For spin stabilised rockets the CP is in front of the CG. Pay attention to the fact that for arrow stabilised rockets we took Δ as a positive value; should have been taken as negative.
From this it follows that the stability of fin stabilised rockets increases with increasing $|\Delta|$ while the stability of spin stabilized rockets decreases with increasing circumstances $M \sim 1$ is obvious from the curves in the diagram. (Although the instability might in principle be removed through gigantica large spin, this solution is limited by the peripheral velocity at which the centrifugal stresses become intolerably large).



Practical importance of the determination of σ

This becomes clear from an investigation of three different caliber length of the D = 15 cm shells. Measured L = 4,122 D; 5,916 D; 6,454 D. The corresponding coefficients of stability for the muzzle velocity were (M = 2,5).

σ 5,35; 1,68; 1,15.

The last shell therefore is instable. For M = 1,56 the values were

σ = 4,32; 1,24; 0,94.

Therefore even if the projectile is stable at the muzzle velocity, this stability is lost later on.

Treibspiegel-Geschosse mit R-Antrieb (Υ = p - k).
==

Definition: Treibspiegel = propulsion disc
Treibring = propulsion sleeve or ring.

Example: Tsp-R-Geschoss 80/52. (Projektile w = tons).

This projectile is fired from a gun of 80 cm Innerdiameter and 52 cm diameter of the shell, which is spin stabilized. (The gun was called "der Schwere Gustav" and was used in the bombardment of Sebastopol. Gun was also called "Dora")

Weight of the projectile was not given to the wind tunnel investigators.

From the "Schwere Gustav" were fired both the regular caliber projectile of 80 cm diameter and the slender projectile of 52 cm diameter. The normal projectile was L = 376 cm long, while the slender projectile is 264 cm long.

Approximately the ranges of the projectiles were

~ 60 km for the	normal	caliber	(4 tons)
40 km " "	heavy normal	"	(W = 7 tons)
? km " "	slender	"	(W 1,5 tons)

Weight of normal projectile 7,0 tons for siege purposes, with a range of about 40 km? For the 52 cm caliber shell, with 4 tons weight, the range was about 80 km?? The 7 tons shell had 690 m/sec. muzzle velocity.

The same gun carriage was supposed to be outfitted with two barrels, one 80 cm and one 52 cm.

The latter was intended for muzzle velocity 1270 m/sec. (The extra R-rocket propulsion was only intended, but not actually executed).

(The Dora was at last near Hillersleben near Magdeburg).

The end spin angle had not been fixed by Krupp. The wind tunnel investigations therefore concerned themselves with a range of U_p/U_o.

For $\sigma > 1{,}3$ and U_o = 840 m/sec. it must be

$$\delta = \text{arctg } U_{\text{peripheral}}/U_o = 6^\circ\ 22'.$$

This angle runs in general between 5° and 7° because the CG from projectile to projectile does not change much.

with U_o = 1100 m/sec. δ = 6° 13'
U_o = 1460 m/sec. δ = 5° 57'

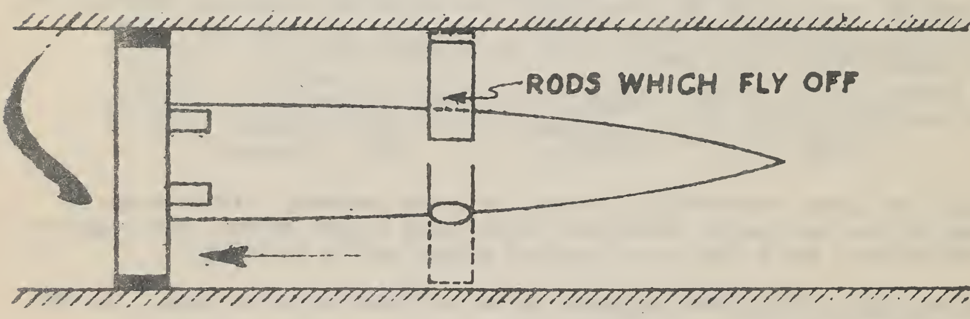
The spin stabilized under caliber projectile had the following end spin angles.

U_o = 840 m/sec. δ = 6° 43' (Up refers to the
U_o = 1100 m/sec. δ = 6° 22' periplery of the
U_o = 1460 m/sec. δ = 5° 56' projectile.)

(not much difference against).

Only the propulsion disc transmits the spin to the projectile while the sleeve ring slides over the rifling.

(angular velocity of the undercaliber projectile ω' is $\omega' = \frac{80}{52} \frac{U_o}{U_o}' \omega$, which is considerably greater than the angular velocity ω of the normal projectile).



(The French also had an undercaliber projectile which was immersed in a low melting alloy sleeve).

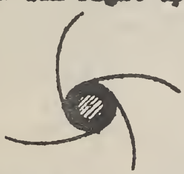
2. Projectiles without rocket propulsion.

A. Arrow stabilised projectiles.

a. Developments at Kochel.

Development starts in the fall of 1939.

The firm "Stahlwerke Rochling" in Volklingen at the Saar had a "LanggeschoB" of L = 20 D. They had the intention to stabilise this projectile by wound up flexible fins which were held in the folded position by a sleeve which was jettisoned at the muzzle. (Photographs exist) was all right up to M = 1,5, but at higher M's the fin sheets begin to flutter and break off.

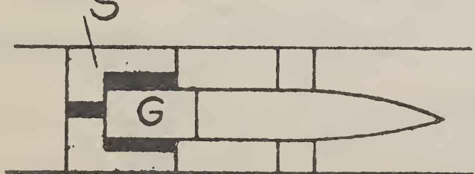


(The "HanggeschoB" was developed for penetration of reinforced concrete)

As "VollgeschoB" (caliber of gun and shell the same) the projectile was only tested as a model which served as a prototype for the under caliber projectile).

On the exact characteristics interrogate Dr. Polts Wa Prüf 1.

Example: Gun caliber 32 cm. Projectile D ~ 20 cm
Muzzle velocity ~ 500 m/sec.
Penetration 10 m reinforced concrete,
and 40 m earth.



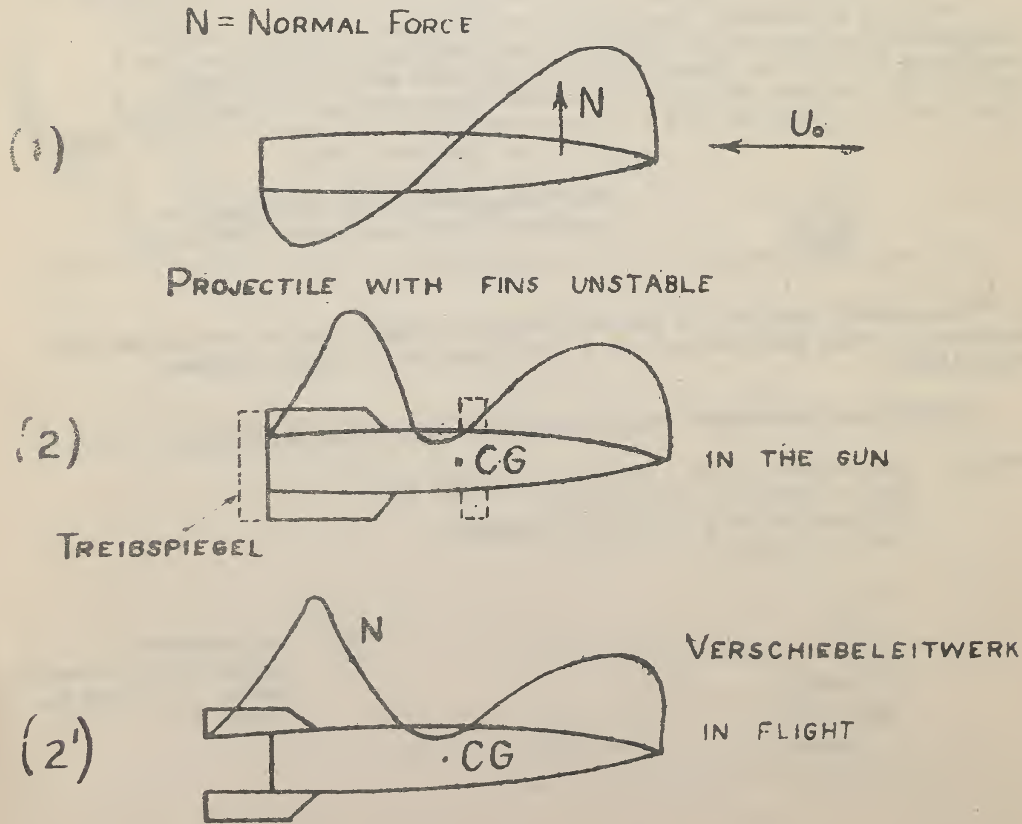
G = Gas chamber filled with combustion gases, kicks off the sleeve S.

The shell 2 was kicked back by collected high pressure gases as soon as the projectile left the muzzle. The guiding ring also fell off. The casing of the projectile was of highly annealed steel (Si-Mn Steel).

Kochel Development.

The fundamental idea was to replace the flexible fins by solid fins.

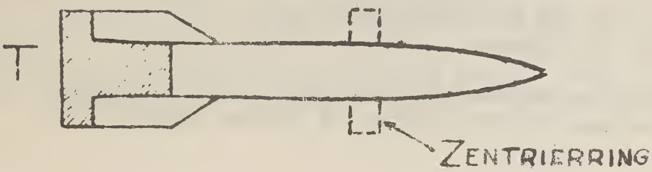
The difficulty was that the flexible fins could be made larger than D, while the solid fins with diameter D, were not sufficient to stabilise the projectile. Therefore Verschiebeleitwerk = fins which were movable backwards were introduced by Kurzweg. The following sketches illustrate the development.



In case 3) the fins were attached to a sliding sleeve which was thrown backwards and the pressure distribution got a larger lever against CG thus stabilising the projectile.

The next idea was not to use movable fins but to weld them in place (3) and to use propulsion prop T.

(3)



T = Treibzapfen is necessary because the fins must be of light construction in order not to displace the CG backwards.

The above arrangement was fired from D_{gun} = 7,5 cm an $D_{projectile}$ = 4,3 cm. These were the first tests which demonstrated that the principle of solid fins is all right. (Range 13 km which is 30% more than the full caliber projectile of the same mass).

The next development was as follows:

(4) Treibflossen. PPG/F (1941 Spring)

Basic requirements: CG as far forward as possible. CP as far back as possible.

Arrangement 3) had too much mass in T (which was 15% of the total weight) and which had to be accelerated uselessly. It was therefore tried to push against the fins directly although as we have said, it looked at first sight, that the fins would be too weak to take up the thrust. The stress analysis of a just strong enough construction of the fins and the shell casing showed that with sufficiently strong fins one could just manage to keep the CG far enought in front to insure stability. The static safety factor on the fins was about 20%. The stability was also just sufficient.

Example: Projectile for the 28 cm Eisenbahngeschütz K5 = Railwaygun.

Projectile D = 18 cm L =

W = Weight 250 kg in flight. Warhead 10% of W which is always about the same for large projectiles. Weight of auxiliary propulsion gadgets = 25 kg (Disk, Sleeve etc). (These new developments were less for penetrating power, but more for increased range. The Langgeschoß is stressed the most on impact while the presently discussed projectiles are stressed the most on firing).

Normal Projectile D = 28 cm.
Weight in flight = 250 kg.

Range = 60 km for the conventional spin stabilized projectile.
Muzzle velocity = 1120 m/sec.

Range = 90 km for the fin stabilised shell
Muzzle velocity = 1150 m/sec.

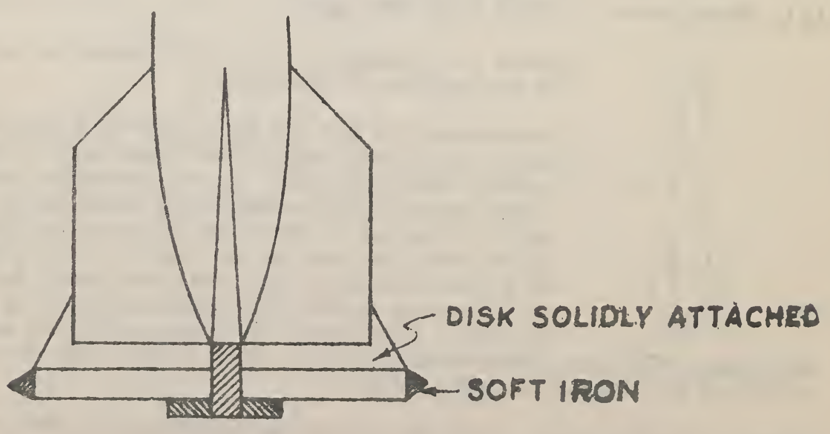
The same powder charge was used for both namely 180 - 190 kg.
Rohrenpulver (Diglakol-Pulver? ignited in various places).

$\Delta \sim 0,2$ D.

The theoretically calculated range was very exactly reached in practice. The deviation was only between 0,5 km and 1 km.

All these developments were intended for smooth gun barrels. The actual shooting had to be done with rifled barrels which fact immensely added to the difficulties since the propulsion disc and ring had to be very exactly worked in order to allow them to rotate freely around the projectile and on the surface of the fins. About 10% of the spin was nevertheless transmitted to the projectile while 90% of the spin generated by the rifling was taken by the propulsion disc.

centering ring also used.



Propulsion disc rotating against the attached disc. C = centering cylinder attached to projectile. P = Pulvermutter which burnt off and liberated the disc from the projectile. The burning off was achieved by a powder charge sandwiched between P and disc.

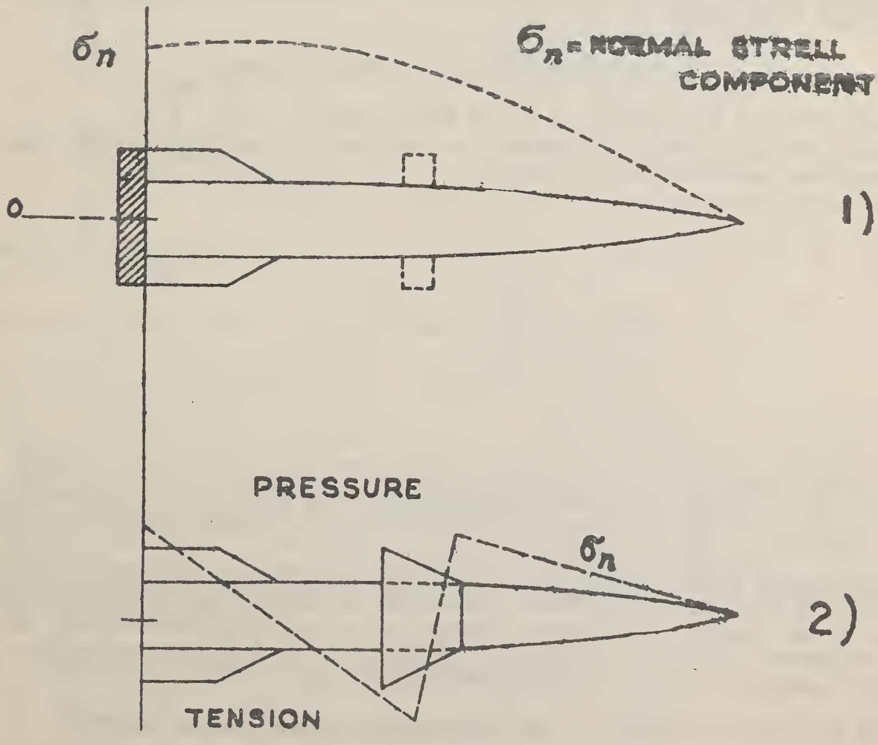
(The idea of undercaliber projectiles is very old, maybe 50 years)

(5) Pfeilgeschoß mit Treibring PPG/R (Fall of 1942).

Scheme 4) had disc and ring which all added to the dead weight.

In development 5) conventional barrels without rifling were used.

In scheme 4) the thrust had to be applied at the tail which had to be heavy with resulting displacement of the CG backwards. The idea therefore is to applythe thrust in a more firward position. There must be an optimum point or region of the application of the thrust from the standpoint of minimum stresses and most advantageous location of the CG.



SOFT IRON COMB WHICH PROVIDES GRINDING

Notice that with the application of the thrust in scheme 2) to maximum stress is lowered. Both pressure and tension are generated.

In case 4) the gain was only aerodynamic.

In case 5) the gain is both aerodynamic and in total weight because smaller stresses have to be taken care of.

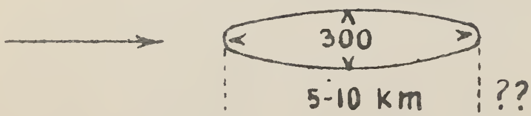
Stresses dropped to about 1/3. This made possible a reduction of the weight below that of the normal projectile, from 250 kg to 125 kg which resulted in the

Unterkaliber - Untermasse - Geschoß.

This was fired from the railway gun K5 with a muzzle velocity of 1480 m/sec. and achieved a range of

151 km (with 250 kg powder charge).

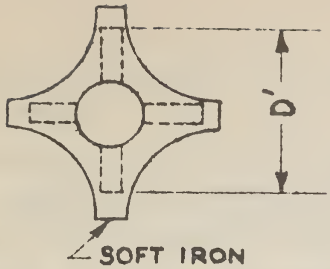
The final velocity U_z (Ziel) is about 800 m/sec.
Combustion pressure 4000 atm. instead of the usually admissable 3000 atm.
Dispersion was maximum 300 m laterally.
Longitudinal dispersion



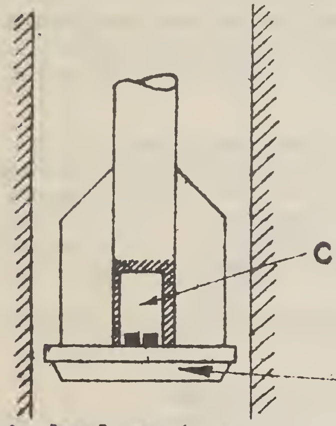
Longitudinal dispersion cannot be discussed yet because it depends on the precision of the ring, the powder charge etc. The development was not far enough advanced to get good statistical data on longitudinal dispersion.

The requirements were reduced to 135 km range for tactical reasons, because one wanted to use the projectiles. About 80% of the new projectiles arrived at the target. Battery at Ahrweiler in der Eifel sudwestlich von Köln. Targets in the southern part of Belgium. The development was not advanced enough to draw any final conclusions.

The fins were often damaged by the explosion. Flight became erratic.



Therefore a star shaped propulsion disc was used, while the fin span was D < D.



In the chamber C at the beginning is under pressure which keeps the starlike disc by suction on the projectile. The disc is thus accelerated with the projectile.
Gas leaks slowly into C, which after exit from the muzzle kicks the disc off.

Even this development was not yet full proof since only 80% of the shots fired were good.

Verschleiß des Rohres = wear and tear of the barrel.

K_{12} similar to the Paris gun of the last world war.
K_{12} is a railway gun of 21 cm caliber and a range of 120 - 124 km and 2 = 110 kg. (Paris gun was stationary gun). Powder charge ~ 350 kg. Number of rounds = 100 before the gun became useless (Spin stabilised projectile). Barrel of the K_{12} was 34 m long. 1500 atm. - Total weight of gun 300 tons.- Weight of K5 ~ 200 tons and 20 meters long; charge 250 kg; weight of projectile 110 kg - smooth tube - range of 130 to 135 km and possible number of shots about 500. These data represent cautious estimates. - Gessner thinks that 150 km and 1000 shots should be possible after streamlining the gun.

The following calibers were intended for the K5

1) range 150 km. $W_{projectile}$ = 110 kg
2) range 100 km W = 200 - 210 kg
3) range 60 km W = 350 - 400 kg

For the "Langer Gustav" the following projectiles were intended.

1) range 250 km W = 500 kg
2) range 150 km W = 1000 kg
3) range 80 km W = 2000 kg

L of the "Langer Gustav" $\sim$ 40 m Länge

Professor Müller at the Krupp works was the development man of these heavy guns.

Examples for smaller calibers.

Normal "Flakgerat" that is anti-aircraft gun of 10,5 cm caliber with a projectile of 7,5 kg flight weight. Muzzle velocity of 1070 m/sec. was obtained with a chamber pressure of p_c = 2700 - 2800 atm. and powder charge of 4 to 4,5 kg.

(Die Rohrabnutzung der glatten Rohre war "erschreckend" klein - the wear and tear of the barrel was frighteningly small). Actually the barrel seemed to shrink slightly. Ordinary anti-aircraft gun is good for 4000 rounds. For how many rounds the smooth tube would have been good for one does not know. Dispersion was about 1°/o laterally and longitudinally. Relative calibers; caliber of gun 10,5 cm, caliber of projectile = 4,5 cm and L $\sim$ 80 cm.

Treffwahrscheinlichkeit = Probability of hitting the target increases with the inverse third power of the time of flight.

(Oberstingenieur Kuhlenkampf is the expert in this line).

Intended was the following scheme:

Projectile of 400 - 500 grams warhead and impact fuze.
Example: the gun would have had the performance of the 12,8 cm Flak gun. Normal spin stabilized projectile would have been ω = 26 kg; $U_0 \sim$ 1000 m/sec., powder charge 14 kg. Time of flight to 10 000 m. Problem was to replace the normal 8,8 cm projectile by a undercaliber projectile fired from a larger gun (12,8 cm and later 115 cm gun of equal m $U_0{}^2/2$ of the projectile at the muzzle).

Time of flight to 8 km of the 8,8 cm normal projectile was 32 sec. and of the undercaliber 8,8 cm projectile shot from the 12,8 cm gun it was 8 sec. (Powder charge about four times as great in the second case). (Estimate of the ratio of weight of the two guns perhaps 1,5 to 1). (This is very very uncertain to the man at Kochel).

Treffsicherheit was therefore 64 times better.

The basic characteristics of the projected gun were

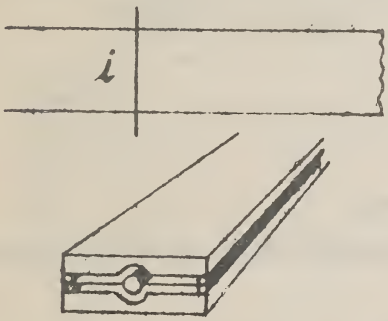
1) Power equal to that of the 12,8 cm gun
2) Gun carriage equal to that of the 10,5 cm gun
3) Weight equal that of the normal 8,8 cm projectile.
4) Muzzle velocity $\sim$ 1500 m/sec. as compared with the muzzle velocity of 850 m/sec. for the normal spin stabilized 8,8 cm projectile.

Practically the improvement in number of hits would probably have been about 30 times.

The anti-aircraft shell had no propulsion disc but only propulsion ring.

The development was for enough to go to the Front and the men think it would have made a tremendous difference.

(6). Projectile for electric cannon.



either batteries or surge generators etc. About 800 m/sec. muzzle velocity was obtained with calibers of D = 5 mm.

A projectile model was designed for the electric gun.

(7) Fascines (bundles) of fin stabilized shells.

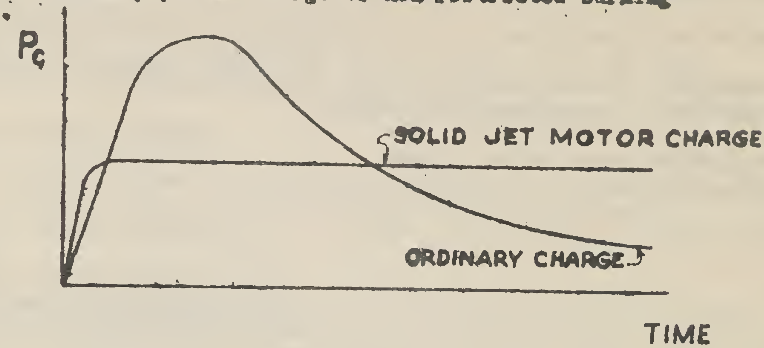
The idea is to fire simultaneously many small projectiles from a gun. The mass which one has with a large projectile was to be subdivided into many parts so as to produce a shot gun effect. All arrow stabilized projectiles were simultaneously ejected through the intermediary of a propulsion disc (see photograph).

Further developments of fin stabilized projectiles.

Panzerabwehrwerfer = antitank guns and missiles.
For instance PAW 1000 (Shell = WHL-Granate 10,5/7,5)

(The real advantage of fin stabilized undercaliber shells is that one can throw double weight equally far as the normal projectile, equal weight further than the normal projectile and smaller (1/2) the weight three times as far).

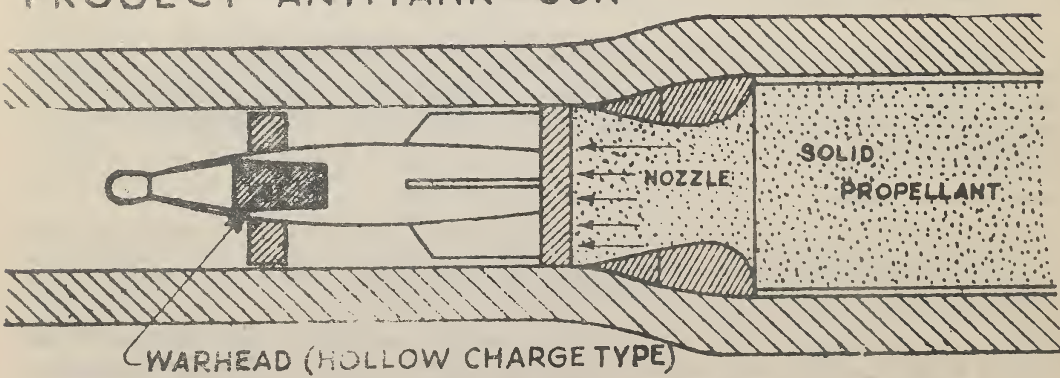
PAW 1000 is an anti-tank missile with hollow charge. High muzzle velocity and target range of 1000 m to 2000 m. It is an undercaliber shell of 7,5 cm to be fired from a 10,5 cm tube. Were to be used from tank to tank or cannon to tank. In the ordinary gun the pressures of 3000 atm. would have been too high, the projectile could not have taken up the stresses. Therefore a light metal tube was used with a powder charge, which is more restricted burning and has no very high peak of thrust (see sketch). To obtain constant thrust as a function of time a solid propellant cartridge was introduced into the gun instead of an ordinary powder charge of non-restricted burning characteristics.



The cartridge had a Laval nozzle (see sketch).

(The hollow charge development was in the hands of Prof. Schardin, formerly in Blankenburg and Gatow).

PROJECT ANTITANK GUN



Muzzle velocity U_0 = 1000 m/sec. was intended.
The chamber pressure is 2000 atm.
The problem at the wind tunnel was to design the tailend of the projectile.
Two schemes were intended one with propulsion disc and one with the propulsion sleeve only.

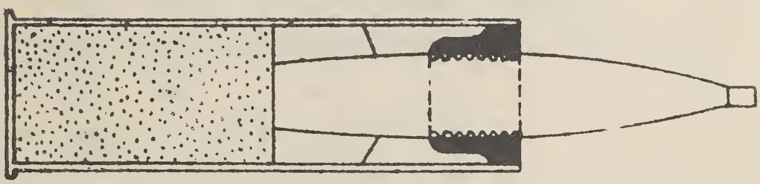
PAN aerodynamic data.

Difficulties: 1) Front part of the shell was prescribed and could not be altered.

2) Ratio of $D_{gun} / D_{projectile}$ = 1,40 too close to unity to be comfortable. In order to get good arrow stability the ratio should be at least 1,55.

3) CG was very far back because of the incorporation of the hollow charge.

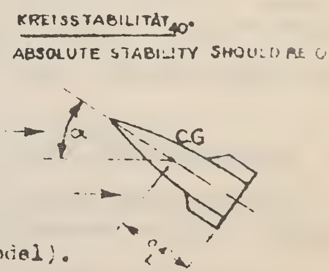
4) Length of projectile was limited because it was mounted with a cartridge and had to be fired from a tank turret.



This cartridge type arrangement was more difficult than the previously sketched jet motor propulsion arrangement because of the higher pressures and stresses which the arrow projectile had to take up.

With the difficulties mentioned above it was almost impossible to solve the problem.

8 differense models of the projectile 10,5 W Hl-Gr. were investigated in the wind tunnel.



Nor. 1 for instance had 8 axis parallel fins. That was not enough to bring the CP far enough back. With the necessary requirements of construction it was not possible to push the CG forward further than 0,41 L.

Another model was as follows (most successful model).

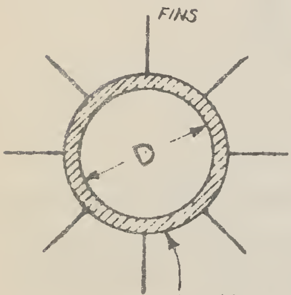
"gegenläufig angestellte Flossen"

With M = 1,86 one gets α = 1°, and M = 2,92 ⟶ α = 3°

Question is why are the mutually inclined fins better than parallel fins? (It seems that the greater stability has its origin in the greater resistance of the inclined fins and not in the higher value of $dc_N/d\alpha$

In addition to the investigation of stability, the resistance was determined. The mutually inclined fins as compared with the parallel fins gave an increase of resistance as shown in the table.

Table for C_D relative to diameter



Fins \ M	1,86	2,92
8 fins	0,39	0,30
8 fins	0,44	0,36
Tail disc + ‖ fins	0,62	0,44

The tail disc gave complete stability, the resistance however much increased.

U_{muzzle} dropped from 1000 m/sec. to 860 m/sec. which was sufficient to reach targets from 1000 to 2000 m.

Kopfringscheibe was tried by Walchner in Gottingen.

B. <u>Spin stabilised projectiles.</u>

a) <u>Conventional projectiles.</u>

A very great number of models were investigated in the Peenemünde Wind Tunnel.

Example: 28 cm caliber "Sprenggranate" for the K5. This was the first example for which the influence of the spin on the aerodynamic characteristic values was determined.

Spiral grooves on the projectiles were used which exactly fitted the rifling. Also the spiral grooves were used to bring the model in the wind tunnel to rotation.

With the ribs about 10,000 rpm were obtained. With "Schnellaufer" motor developed at Gottingen 6000, 12000 and 18000 rpm were obtained. In this case the shells were smooth.

The theoretically necessary angular velocity for stabilization was not actually reached for the models in the wind tunnel.

No systematic series of measurements were made, but a noticeable increase of C_D was observable at

$$U_{periphery} / U_{forward} = 0{,}09.$$

The path of the projectile which was calculated on the basis of the experimental data gave ranges which coincided with the theoretical predictions.

Other wind tunnels predicted results for ranges which were 15% to 20% less than those obtained from actual firing. It was found that the difference in C_D came from the difference of the viscous drag (Reibungswiderstand) on different sized models.

B) Spin stabilized undercaliber projectiles.

Examples: Projectiles for the 8,8 cm gun with caliber of 7,2 and 7,0 cm for the projectiles.

(Bochumer Verein, Rheinmetall Borsig and Firma Stock were involved).

: CP : CG was determined and with prescribed $U_{periphery} / U_{muzzle}$ it was possible to give the manufacturers the necessary information of how to change the location of the CG which would guarantee stability.

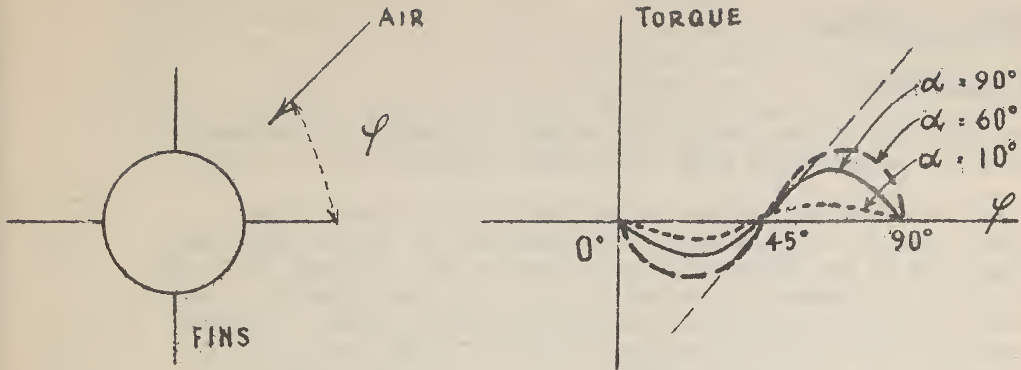
- - - - - - - - - - - -

Additional remark

Influence of the flat nose of the fuze on the C_D of 5 cm anti-aircraft shell L/4,7.

Analyzed were the shell with the normal flat fuze (for data see table).

Point	C_D ($a = 0^\circ$)	Flat top of fuze in calibers
1	0,223	0
2	0,219	0,084
3	0,224	0,18
4	0,260	0,28
Original nose	0,270	0,39



Body stable at $\varphi = 45^\circ$ and unstable at $\varphi = 0^\circ$

Schmeller analyzed the forced motion of a spinning top which is subjected to a torque as shown in the diagram. The diagram had not at that time been experimentally determined, but some reasonable assumptions were made. (The body described exactly a "moon" rotation in the sense that a given meridian of the body always faced the axis of rotation).

From these investigations it became apparent how important the spin is.

The tumbling motion comes from three effects.
Axial spin is necessary in order to maintain the moon like motion which guarantees the same sign for the azimuthal moment of force. (This moment of force originates in a lateral lifting force). The polar moment of force originates in the rotational asymmetries and in the effect of the lateral wind. The pitching moment is in equilibrium with the centrifugal moment.

3. Additional Notes

A. Rheintochter.

At one time it was though that in order to avoid the influence of the slip stream on the fins, the rudders should be put in front.

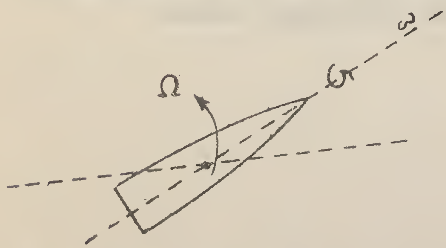
At first the Rheintochter had 6 fins and six wings, later 4 fins and 4 wings. Hinge moments were measured and it was found that for some axes of the rudders unstable moments were obtained while for other axes stable moments resulted. It is not clear whether or not the idea of putting the rudders in front is of any value. However, one may state that with the rudders in front the CP would move too far forward if one did not use larger wings to compensate for this forward displacement. The Rheintochter consequently has much larger wings than the Wasserfall (perhaps two to three times).

B. A 10.

No experimental work done at Kochel or any other place.

Was intended to be a 100 ton thrust mother rocket and an A_4 or A_9 25 ton thrust daughter rocket. Was planned for perhaps 3000 km ?? range. 1940 some analysis was made but not seriously.

C. Taumeln = tumbling of projectiles.



If $\omega \sim \Omega$ the tumbling occurs. Since $\Omega \sim 1$ to 10 H_z. Therefore the undercaliber projectiles were given inclined fins to produce the necessary large $\omega > \Omega$ right away.

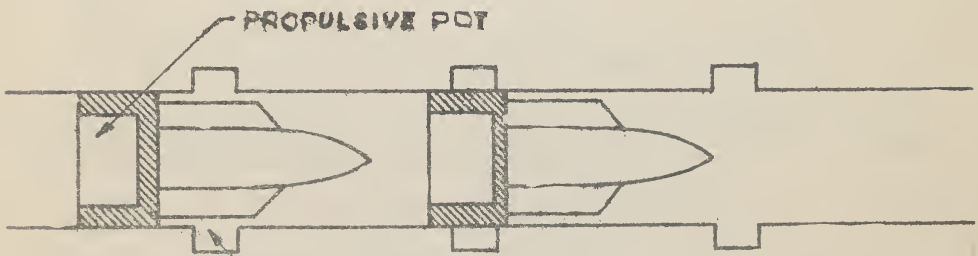
Dr. Schneller (who got killed in an airplane accident) calculated the tumbling effect theoretically which was checked in wind tunnel tests on a model suspended on a universal joint and which could be made to spin at different angular speeds

3

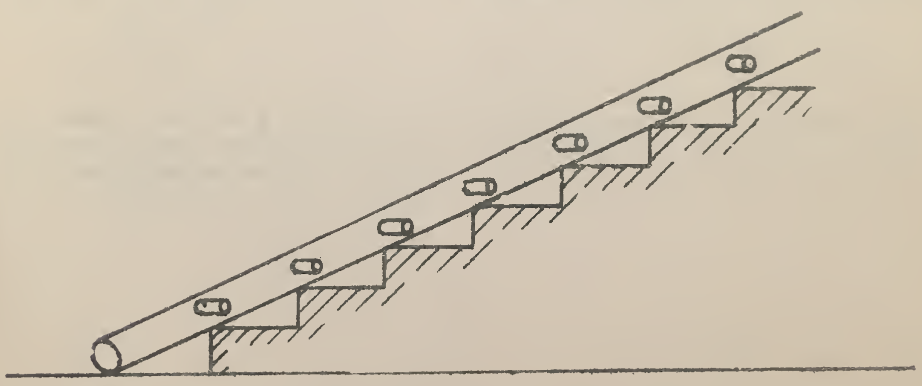
When the projectile passed the successive explosions were initiated. Actually 1300 m/sec. was reached. 2000 m/sec. was intended. Diameter of the tube was 15 cm and the projectiles weighed about 80 kg. Bad oscillations of the gas column occurred and the whole project was a flop because gas dynamically the various phases were not thought through. Also it was so little manoeverable that the K5 was vastly superier (which made easily 150 km with 80 kg projectiles).

D. Hochdruckpumpe (HDP), Himmelsleiter).

Goenders bei Rochling (Volklingen an der Saar) was the inventor and the promoter of the scheme of staggered explosions and they convinced Hitler.



Was tried in the neighbourhood of Swienemunde. Misdroy on the island Wollin in the Baltic.
Tube was 120 m long.



Abstract of Report on the 38 cm Rocket assisted shell.

This is a report of measurements on models of the 38 cm rocket assisted shell which was being developed by Krupps. Hermann says that the 28 cm shell was used during the last year of the war to bombard England. The 38 cm was never used and they have not a very high opinion of it at Kochel because the dispersion was high. It was intended to ignite the rocket propellant 15 sec. after launch from the gun.

These projectiles are the ones which were found at Krupp's range at Meppen and were sent to England. Only the propellant of the 38 cm was found but complete examples of the 28 cm were sent to England and should be available at P.D.E.

The following details are given in the report:

Model used was on the scale 1 : 8.44 (see H.A.P. Archiv 66/93 for experimental method). The two types of 38 cm shell are as in the table.

Type	Length (calibres)	Ogive Radius (calibres)	Fuze Tip	Projectile Base.
Form A.	4.52	8	pointed	with plate
Form B.	4.36	10	blunt	without plate

The center of pressure lies fairly far forward with both types and migrates towards the base as the Mach number increases, with Form A this migration is more pronounced than with Form B.

The results of the tests on the models indicated that there is no essential difference between the two Forms from the aerodynamic point of view. A reference is given to a report by Krupp, A.K. No. 12518 geh. of F. Krupp Div A.K. 2.4.43.

The "Enddrahlwinkel" proposed by Krupp was 5°59' and at this angle only Form B was stable. (Experience has shown that for stability in flight coefficient must be not less than 1.3. As the aerodynamic data are so similar for the two forms the reason for the difference between their stability coefficients must be principally in the different equatoxial moments of inertia, the moment for Form A being twice as large as for Form B.

Report on Possibility of Cooling Hot Gases from Rocket Jets.

By Dr. Grünewaldt & Dr. Klans.

Archiv 66/94 g. Kdos dated 26.3.43.

This is a theoretical calculation of the cooling system necessary to reduce the temperature of the gases in a jet from 2.000°C to 400°C. The special application was in connection with static tests of A4 and Wasserfall.

The data for Wasserfall are as follows:

Combustion chambers pressure 15 atmospheres

" " temperature 3000 °K

Velocity of jet at exit of Venturi 1900 m/sec.

Temperature of jet " " " 2300° K

Static pressure at exit of Venturi 1.2 atmospheres

Composition of gas jet is approximately as follows (by volume)

50% H_2O

1⅔ 2/3% CO_2

16 2/3% CO

16 2/3% nitrogen compounds. (K cal. 1 litre)

Specific heat (Cp) = 0.42 Kcal/kg

Mass discharge rate 500 m^3 /sec.

Rate of fuel consumption 60 Kg HNO_3/sec
12 Kg "Visol"/sec

With the special cooling system used at Peenemunde it was calculated that 0.5 m^3/sec of water would be needed to cool the gases from 2.000°K to 400°K the cooling efficiency being 20%.

Recent work of the WVA

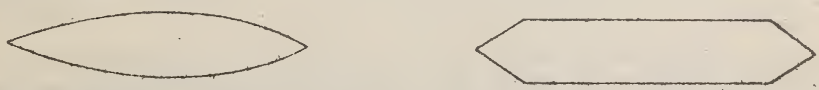
Every month there were about three reports. Therefore the reports are up to date except for some items such as:

a) The wind tunnel investigations on the projected A9 (A 4b) are not yet incorporated in any report.

b) Review on Rudders for subsonic and supersonic controls by Wegener is also not incorporated. This report was taken away by a member of one of the American visiting parties. (Can be rewritten by Wegener)

c) "Arrow projectiles" to be fired from 10,5 cm guns without rifling (projectile PAW 600, and PAW 1000, PAW = Panzerabwehrwerfer, the number gives the approximate muzzle velocity in meters per second). These projectiles were intended for anti-tank use and a head was used with hollow charge and forward jet. - Prof. Schardin, first at Berlin-Gatow (Luftkriegsakademie) and later at Blankenburg was the German expert on the hollow charges, on penetration of projectiles etc. (Dr. Lehnert could work up some of these reports).

d) Some investigations have not been reports on which concern themselves with the basic phenomena on "Tragwerk" (pure lift surface) = "Tragflugel", "Leitwerksflachen" = "Flossen" = stabilizing surfaces and Luftruder = control surfaces. Types of profile:



for M = 0.4 to 3.0

e) Calculations were also made on skin temperatures of the A9 and Wasserfall. (For the A_4 and longest range the temperature of the casing reached 600°C just before the dive 10 seconds before impact, while the boundary layer temperature is about 1100°C). P. Jordan was also engaged in this connection.

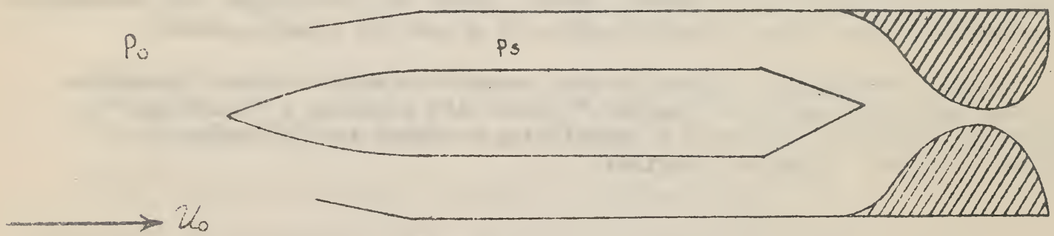
(Greybody assumed. Equivalent temperature T 0.65)

f) In gasdynamics the methods of Tollmien and Sauer were used to determine the pressure and velocity distribution about bodies with rotational symmetry. The different types of methods of calculation were compared for convenience and speed.

Some work on the theory of 2 dimensional Laval nozzles up to Mach numbers 10 also was done which is not contained in the reports. (Mutter- und Tochterdusen, means that a standard nozzle for M = 10 is first analyzed and all intermediate cases can then be relatively easily derived).

g) Supersonic flow through aeroducts was studied recently for the purpose of jet propulsion and increase of range for the A9. The work was done both at Kochel and Gottingen where Oswatitsch worked on what is called "Stossdiffusoren" (Diffusor efficiencies for supersonic air intakes. Oswatitsch's work was published in the ZWB (central agency for scientific reports.) At Kochel the following types of diffusors were tried. (See sketch).

At Kochel they worked only a few weeks on aeroducts but they think that aeroducts will be important at supersonic speeds and in relatively dense air. Two difference ducts of the type sketched were tried as models.



Special attention was paid the problem to achieve maximum ratio p_s/p_o for given U_o. Oswatitsch was generally concentrating essentially on the front end intake (all the time adjusting the exhaust flow through a movable plunger in the exit).

"Drosselfaktor = diffusor efficiency)

Another problem which they intended to solve was the determination of the drag coefficient of the aeroduct, in dependence of Mach number and yaw. (Zobel measured in Volkenrode drag coefficients for the "Arguserohr" = intermittent motors).

H. Photo-electric proximity fuze developed at Kochel.

This fuse works on the principle of sending out flashes of light and detecting the rays reflected from the target by means of a photo-electric cell.

It was being developed for the guided anti-aircraft projectile "Wasserfall".

Dipl. Ing. Peucker and Dipl. Ing. Hoh have been doing this work more or less in their spare time as the establishment at Kochel does not normally do this kind of work. They have spent almost 18 months on the development and it has reached a stage where complete models have been constructed and ground tests carried out, but no tests have been done with the fuse on the projectile nor have any "fly-over" tests been made with an actual aeroplane.

Archiv Nr. 180 and Archiv Nr. 181 are preliminary reports on the fuze and amplifier respectively.

These two reports give most of the information available and the following is a brief outline of the main points together with some details not included in the report.

Model I.

A flat photo-cell is used with a solid glass nose so that the light reflected from the target is directed on to the cell by total internal reflection and refraction. The layout is shown on the figure attached. The tip of the fuze nose is made of steel (aluminium was tried but had too low a melting point).

The light from a filament lamp (12 V 100 watt) was sent out in a series of flashes by means of a system of lenses mounted in a rotating mechanism. The lens mount is driven by a small electric motor at a speed of approximately 20,000 revs. per minute and as there are six lenses equally spaced around the circumference, 2000 flashes per second are sent out. The lenses have a focal length of 3,5 cm. In this model, infra-red filters were fitted over the lenses at first but when the objections to using visible light were removed the filters were omitted, thereby giving an increased sensitivity to the fuze.

The photocell is a flat, gas-filled red-sensitive cell made by Pressler of Leipzig. Various types of sensitive surfaces were tried and the type used finally for this model was caesium + some organic substance, which was developed by Pressler. The cell is designated "Special I" by the firm. The sensitivity is quoted on the test sheets as being 700 microamps per lumen with an anode voltage of 100. (The max. anode voltage is 145).

The amplifier on this model operated the fuze when the photo-cell received only one flash of the reflected beam and was therefore liable to be operated by any accidental flash of light.

No arming devices were developed but there was a delay relay incorporated which would prevent the full voltage from being applied to the lamp until 10 seconds after the projectile had been launched. This delay was merely a wire through which current was passed to heat it to the melting point.

A range sensitivity of 15-20 meters was claimed, the tests being carried out by reflecting the beam with a black cloth in order to simulate operational conditions with a night fighter.

Model II.

This was an improved version of I, the main difference being a new type of cell mounted in a hollow glass nose.

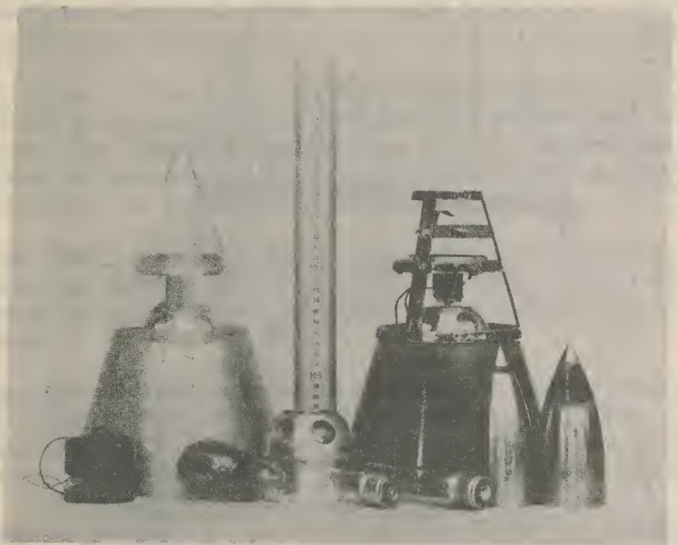
The cell was made by AEG. It is tubular in shape with a caesium coating on the inside of the envelope made thin enough to transmit light. In contrast to the earlier type, this is a vacuum cell having a sensitivity (taken from AEG test sheets) of 10 - 60 micro amps per lumen, anode voltage 100 (2360° K).

The [illegible] advantages of this second model were 1. The thickness of the glass walls of the nose was nearly the same throughout. In the earlier model, heating of the solid glass cone had caused trouble.

The photo-cell was simpler to make and therefore could be obtained in large numbers.

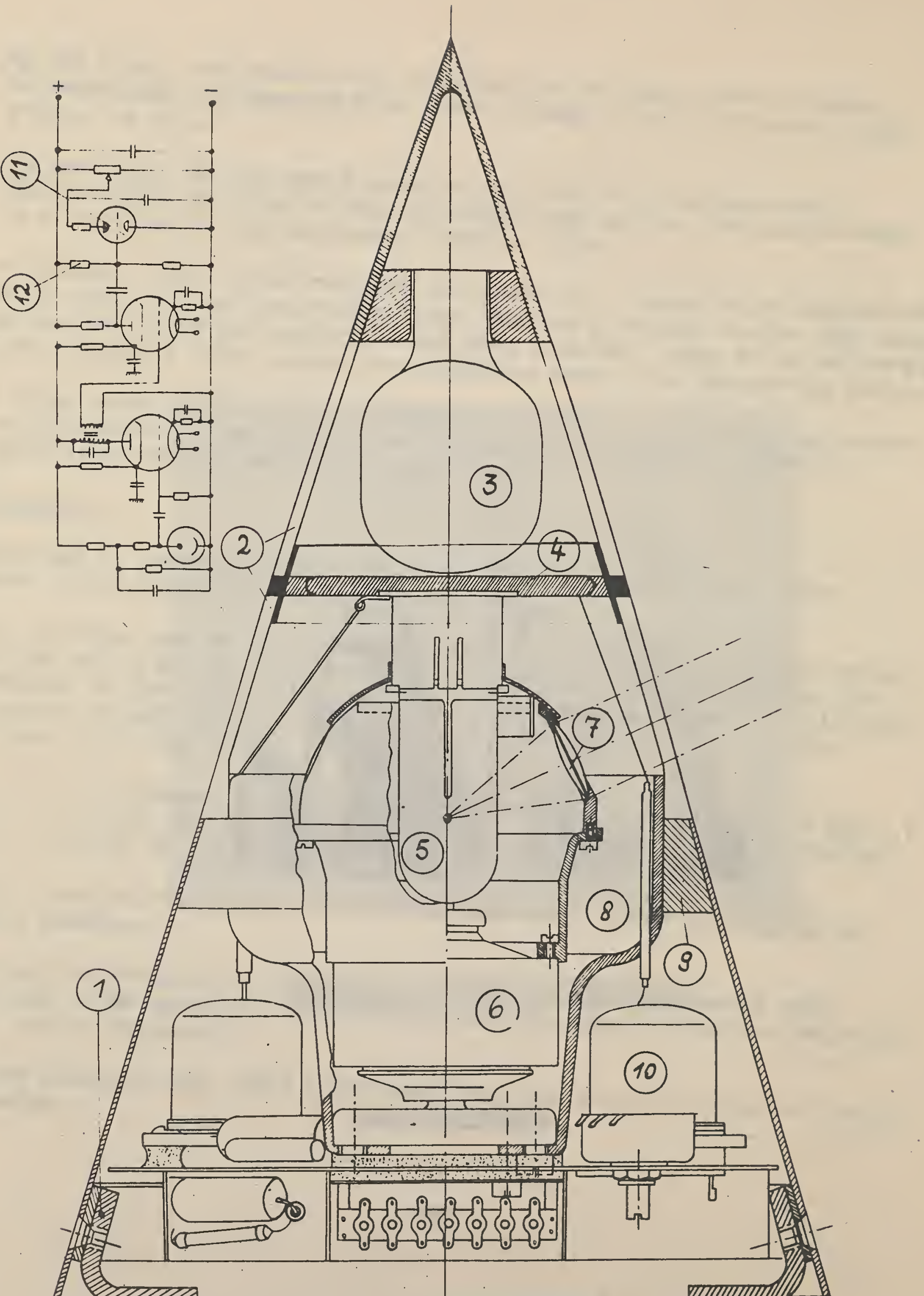
Another improvement in this model was that the amplifier would only operate if the photocell received at least two signals from the target at the correct frequency.

A more powerful lamp (29.5 V 230 watt) was used and also lenses of larger diameter.



MODEL I MODEL II

PROXIMITY FUZES



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SECTION III

Basic Researches of Gasdynamics, Aerodynamics and Thermodynamics.

1) Theoretical Gasdynamics.

There are several investigations concerning the stream in Laval nozzles and the application of the "Prandtl-Busemann-method" with corrections to implicate the boundary layer for the purpose of getting a homogenous parallel stream (Reports No. 31, 32, 36, 56).

A lot of theoretical work was done to examine the universal, stationary and straight shocks in the Laval nozzles and the thermodynamical base of entropy was discussed. To this task belongs a detailed investigation of the "straight condensation shock". (Reports No. 22, 24, 50, 71, 72).

By order of the WVA Prof. Tollmien, Dresden, evolved the possibilities of calculating a supersonic stream with rotational symmetry. The pressure distribution for the body of the A4 was calculated with this and another method of Prof. Sauer, Aachen, and compared with the experiment.

The "Quell-Senken-method" first used for supersonic speed of v. Karman and Moore, was used to calculate the distribution of pressure for bodies with rotational symmetry and compared with the experiment. (No report).

The theory for the infinit wedge and cone was evaluated with a lot of special diagrams and nomograms for convenience. The headwave of cones was examined in a series of pictures taken with the Schlieren method and compared with the theory. (Reports No. 81, 101. 126).

2) Mathematical Investigations for the Stability and aerodynamical Damping of fin and spin stabilized Projectiles.

The first problem distinguished the aerodynamical moment and damping of vibrating fin stabilized models in the stream. The solution was a coefficient withou dimensions for the damping. The conditions of increasing and decreasing vibrations were determined. The mathematics proved that there are several charqcteristic slopes (linear, cubic or universal) of the moment coefficient for interpreting oscillograms of models vibrating in the wind tunnel. The exact difference between models and originals with moving center of gravity was examined. (Reports No. 15. 16, 29, 48, 112, 119, 132).

Other investigations defined the stability of spin stabilized projectiles with another special coefficient and proved the result with wind tunnel experiments. The results were especially used for a spin stabilized rocket projectile (DOV 35 cm) with a velocity near Mach number 1,0 (Reports No. 54, 55).

3) Theoretical Investigations concerning Trajectories of Projectiles.

A special group of the mathematic section calculates the trajectories of conventional projectiles, "Peenemunder Pfeilgeschossen" (PPG) or rockets. For this purpose they developed their own integration method. This method can be used very quickly and with great accuracy. (Report in work).

The important effect of lateral wind on the control steering of a starting rocket was examined. Another work cleared the influence of weight and earth rotation on the trajectory of long range projectiles (PPG, 130 km). It was planned to drop models of "Wasserfall" from an altitude of 8 to 12 km which reach a supersonic speed. Several trajectories were calculated to make the experiments easily (Reports 1, 21, 37, 40, 60, 129, 156, 160).

4). Calculations and Experiments to slow down Rockets of high velocities.

To get subsonic test rockets back undamaged calculations were made for special parachutes. For high supersonic velocities the WVA suggested "Bremsklappen", aerodynamic brakes which allow the fins to open during the flight. The forces were determined and compared with several experiments (Reports No. 7, 8, 17, 19, 26, 45, 111).

5). Other theoretical Investigations.

A special mathematical work solved the problem of the light stream in the great "Schlierenoptik" (50 cm mirrors) to increase the sensitivity. The accuracy of the wind tunnel balance with 3 components was proved. (Reports No. 58, 59, 109).

6). Examination and Supplements of the Wind tunnel experiments with flying bodies.

In the first years of the action of the WVA tunnel (1938-40) was the main task to compare the results of the experimental methods on models with projectiles and rockets. Extended tests with a great number of rockets with several shapes of fins and extreme centers of gravity were made. Calculations were necessary to compare wind-tunnel experiment and flight. (Reports No. 6, 9, 13).

Besides this were dropped a great number of A4 models from air planes flying with an altitude of 6-7000 m to study the behaviour of the model reaching the velocity of the sound. No wind tunnel can examine the behaviour of models at Mach number 1,0 (Reports No. 3, 35).

7). Theoretical and experimental investigations concerning the Heat transfer.

The important question of the heat transfer from the boundary layer and the temperature of the skin of supersonic rockets needed accurate examinations because all the conditions are unknown.

A great number of basic experiments were made in the whole supersonic region to measure the temperature and the heat transfer on several simple bodies (sphere, plate, cones of all angles) in the WVA wind tunnel. The influence of the Reynolds number in this case must be determined with new experiments. (Reports No. 2, 57, 170).

Other theoretical work examined the propagation of the temperature as function of the time by calculation and graphic methods for glass and other materials. As a supplement the infra-red rays of the boundary layer of bodies flying with high velocity was calculated. These problems were important to the building of fuzes for A4 and "Wasserfall". (Reports No. 127, 151, 116, 125).

8) Aerodynamical basic Research.

Fundamental research was necessary in order to have success in the whole aerodynamical developments. Many problems were discussed with the scientific commissions.

Some of the missing points are as follows:

Large investigations were made in stationary blowing wind tunnels with small sections including the compressible subsonic region, the region close to Mach-number 1,0 and the supersonic velocities. Measurements of the pressure in the stream were made with several probes to control the homogenous distribution of the velocity, and investigations were made to examine several shapes of diffusors for the purpose to determine their efficiency in getting the pressure back. The purpose was to get a good shape of diffusors for new stationary blowing tunnels (Reports No. 41, 169).

A lot of experiments had to clear the influence of several shapes and sizes of holes on the surface of models to make an accurate measurement of the pressure in the supersonic region. (Report No. 47).

The elimination of the forces on the holder of the wind tunnel balance is solved by successive measurements using two different holders. (Report No. 93). The effect of the holder on the drag by disturbing the wake was tested on spheres using several sections of holders in the supersonic region. The influence on the result is very small if the ratio of the sections of holder and model are lower than a fixed value. (Report No. 46).

It is very difficult to get aerodynamical coefficients with the rocket jet. At first all results without jet were interpreted. The effect of the jet was determined afterwards by measuring the pressure distribution on the tail of the model. For this purpose the jet could not be disturbed and the model was fixed with a lateral holder. The jet's effect on the aerodynamics can reach very high values. (Report No. 23, 105).

The influence of the Reynolds number on the results was determined with measurements of spheres in the supersonic region (Report No. 46).

Besides the latter, measurements of the drag of a series of simple projectiles in the WVA wind tunnel gave in comparison with the results of Prof. Walchner, Gottingen, most interesting directions with regard to the Reynolds number (Report of "GeschoBtagung Peenemunde" 1941).

The effect of skin friction on the A4 was determined approximatively by calculating the boundary layer (Report No. 105).

For the purpose of getting a homogenous parallel stream in Laval nozzles theoretical and experimental investigations were made to examine the boundary layer in the supersonic region. (Reports No. 36, 56).

The effect of the spin on the aerodynamics of projectiles has been tested only on two examples. The experiment demonstrated that the drag alters only about one per cent.

INTERROGATION OF WEGNER ON AERODYNAMICS OF "WASSERFALL"

at Kochel, 16 June 1945 by RH Norris

References: Report WVA 171- a summary of the "Wasserfall development from the point of view of aerodynamics.

Report WVA 150 - Damping tests of "Wasserfall" model.

PURPOSE OF THE INTERROGATION:

The purpose of this interrogation was to obtain answers to certain question regarding XXXXXX design of Wasserfall, particularly as to reasons for certain design features. A more comprehensive report on the aerodynamic work at kochel, not in preparation but soon to be available is being prepared by Dr. Zwicky.

LIMOTED RANGE OF CENTER OF PRESSURE:

The outstanding feature of the aerodynamic performance of the latest designs of Wasserfall is the small ange within which the center of pressure is confined while the Mach Numbe varies from zero to 2.9, and the angle of attack up to 8 degrees. For a given angle of attack the range is only 0.3 calibers, and increasing the angle from 2 degrees to 8 moves the center of pressure aft only 2.0 calibers for a given Mach number. The overall length of the missile is 8.9 calibers.

This favorable feature of the performance was the result of "cut and try" methods, using various combinations of wing designs and rudder designs in wind tunnel tests.

Accordingly, the major justification for the latest design of wings and rudders is this center of pressure behavior, rather than the drag value. This applies particularly to the choice of the ratio of wing span to wing chaor, and to the location of the stabilizing fins and rudders in line with the wings, not displaded 45 degrees around the longitudinal axis.

No systematic tests of body alone, wings alone, etc have been made, so the design is entirely empirical.

BODY SHAPE

The body shape is made up of a nose of 10 caliber radius tangent ogive, and a cylindrical body piece 4 calibers long joining them. The Diameter of roughly 0.6 calibers at the end of the tail was chosen as small as the exit area of the nozzle permitted, after provision XX for the rudder and vane operating mechanism. Enlarging the nozzle exit area to most the maximum body cross sections may be worth XXXXXXX considering, however, Wegner said this is done in "Taifun".

The body diameter was determined by the size of the required pressure tank sphere, which was based on the original performance specifications and estimates based on them.

The reason for a choice of 10 calibers for the nose radius is not know + Wegner. It may ha e been due to experience dating back many years, an may be relat d to ractical considerations of construction, he said. He admitted that ogive radii as high as 20 calibers have redently been used on fin-stabilized projectiles for guns.

Glass was to be used eventually as the material of the nose, to permit use of a proximity fuze, but all flightest samples so far tested had had steel noses.

DESIGN OF INGS AND FINS:

A sweep back of 60 degrees from the transverse axis is used for both wings and tail-fins. This choice was the result of tests of various amounts of sweep back, Wegner said, but no details or references on this point were obtained.

The wing and fin thickness at the base, (adjacent to the body) was 0.0705 calibers, and tapered to 0.0127 calibers near the edges, where it was brought to a point with a 0.955 caliber-raduis tangent ogive.

The tailing edge of the tail-fin, adjacent to the rudder, was cut off square for simplicity of construction. A test with the edge groved to give a better fit with the rounded leading edge of the rudder, had been made, but the improved performance was considered too small to be worth the additional complexity.

No comparison of the aerodynamic performance by theory, for comparison with test results, had been made, although they had hoped to do so soon. The complexity of the geometry of the wings and fins makes the problem rather complicated and difficult.

The wing profile was dictated partly by considerations of ease of fabrication, and was not considered necessarily final.

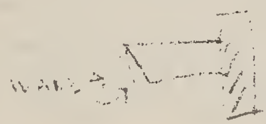
For production samples, full size, the leading edge of the wing was to have a 2 millimter radius, not a sharp edge, and was to be formed by bending a continuous piece of sheet metal. The wind tunnel samples were sharp-edged, however.

Wings were provided in two planes, at 90 degrees to each other, rather than inonly one plane, in order to simplify the problem of guiding of the missile. Much study had been given to the possibility of guiding with wings in only one plane, but the conclusion was unfavorable.

A wing consisting of a cylindrical sheet, l rger, but co-axial with, the rocket body, was tried but found to have excessive drag at supersonic speeds, due to the chiking effect in the space between the wing and the body.

The effect of aspect ratio of the wing ahd been investigated in onl a few tests were the center of pressure, but not the drag or lift, was measured. The span, from the body to the tip (not from tip to tip) was 1/3 chord. The center of pressure at supersonic speeds was only about 30% aft of the leading edge, not 50% as expected from theory. Furthermore this result was insensitive to changes in profile. A combination of wedges for the leading and trailing edges, joined by a flat portion, had the center of pressure location which was independent of the angle of attack.

No trial had ever been attempted of a wing tip cut back so that the shock wave wake from the tip would flow back without being interfered with by the wing.



DESIGN OF RUDDERS:

A great many different rudder designs had been tried in order to obtain the combination of a small variation of center of pressure with angle of attack, together with reasonable hinge moments and absence of an S-shaped curve for angle of attack as a function of rudder angle.

Two rudder designs were chosen as alternatives for the best final designs. These are designated as R12 and R21, and rockets using them are designated as C2/E2 and C2/E3 respectively. R12 has a somewhat greater chord than R21, which results in greater hinge moments, particularly at supersonic speeds, but its curve of angle of attack versus rudder angle extends to greater angle values before becoming S-shaped.

Use of tabs (Flettner Ruder) to reduce the hinge moment of the rudder has been investigated but the test results were not yet conclusive. Enough tab to bring the hinge moment to zero at supersonic speeds is considered impractical however, because the performance at subsonic speed is too unfavorable.

Spoilers, as an alternative to the conventional rudders, were considered, but tests showed that aerodynamic effect practically disappeared at high Mach numbers (above 2), so spoilers were considered out of the question for Wasserfall. Wegner understood however that spoilers were considered promising by Henschel for use on "Zitterrochen" (a further development of "Schmetterling" Hs 117), for use up to Mach number of 2. On that missile the spoilers were the trailing edge type, located on the wings, which were triangular in shape; the missile had no tail fins.

Rudders located at the nose, as on "Rheintochter" have been investigated but conclusive results have not yet been obtained.

They have many disadvantages as well as advantages.

RELIABILITY OF WIND TUNNELS RESULTS:

The reliability of the wind tunnel esults fo: drag is indicated by the very good consistency between drag obtained by force measurements on the model with drag computed from measurements of the normal pressure distribution on the same model, corrected for the calculated ag from the fric ion shear forces. Friction itself had never been determined by test on rocket models.

Measurements on rockets in flight, to obtain aerodynamic data as to drag and lift had never been made with sufficient accuracy to permit confirmation of wind tunnel results. Other problems to be studied by the flight tests had been considered of greater ugency. Drop tests on a conventional bomb, however, had provided a good check with wind tunnel resuults, on the same bomb, made both at Kochel and at Göttingen.

EFFECT OF PRESENCE OF THE JET:

The pr sence of the jet was found to increase the drag by 70% at a Mach number of0.2. This effect decreases about linearly with increasing Mach Number, becoming zero at about Mach number of 1.0. At Mach Numbers above 2.0 the effect of the jet is to reduce the drag about 12 tc 15%.

This effect at subsonic speeds is presumably due to the entrainment of air along the tail, which causes a lower pressure there. This might be improved if the jet exit diameter were mo e nearly equal to the maximum body diameter.

The effect of the jet a super onic speeds is due to the fact that it causes the separation point of the boundary layer on the tail to move forward, which causes the pressure at the tail to rise, thus adding to the thrust effect. This benefit would be reduced by using a larger nozzle exit diameter.

The effect of the presence of the jet on damping is very great at subsonic speeds, it makes the oscillation in pitch or yaw almost a periodic . The effect is much less at supersonic speeds, but the accuracy ther in the tests was too poor to yeild quantitative results.

The effect of the jet on the influence of the rudder angle, was found to be negligible when the pitch and yaw angles were constant.

DAMPING WITHOUT THE JET:

The damping coefficient Cd is 3 ± 25% over the whole velocity range. Cd is defined by the equation: $C_d = \frac{24\ R}{L^2\ D \rho\ V}$

where:

D=max. diameter of the body
L=length of the missle
v=velocity
ρ=density of the air
R=coefficient of the $d\alpha/dt$ term in the differential equation of oscillation in pitch or yaw.

MODEL DIMENSIONS:

The caliber of the usual models was 31.4 mm.

The tolerance for the fins was 0.05 mm., both specified and realized, and for the body was 0.10 mm specified and 0.05 mm realized.

For pressure distribution test, only one half a model, split lengthwise was used, and the body diamter was then greater.

The Peenemunde Wind Tunnel as an Artillery Aid.

The Peenemünde wind tunnel, the most powerful and best equipped in Germany, was specially designed to aid in the development of missiles flying at supersonic speeds. The people associated with this tunnel, which was moved to Kochel in the later stages of the war, were pioneers in the field of applying wind-tunnel data to the development of rockets and projectiles. This report will attempt to indicate the importance of such data for artillery problems. A full discussion of the work done by this group will be found in the report of C.I.O.S. 183, the team which investigated the tunnel at Kochel (Ref. 1). An important booklet dealing with fin-stabilized projectiles is "Geschosse ohne Drall", Deutsche Akademic der Luftfahrtforschung, 1943, (Ref.2). The wind tunnel itself and the fundamental principles underlying the application of wind-tunnel data to projectiles are discussed in "The Supersonic Wind Tunnel of the Heereswaffenamt and its Application in External Ballistics", which has been translated by a member of C.I.O.S. 183 (Ref.3). All these documents should be available soon.

Projectiles With Spin

No original work on the development of spin-stabilized projectiles was done by the present group. But the making of 3-component (lift, drag, pitching moment - see Ref.3) measurements in the wind tunnel enables one to say definitely whether or not a given projectile will be stable in flight. Measurements of this kind were frequently made.

How the rotation of the projectile affects the aerodynamic forces on it has been an open question. The indications are that such effects are negligible for the following reason. The wind-tunnel data were always obtained on non-rotating models of the actual projectiles; predictions about the stability or instability of the projectiles were then made on the basis of these data. These predictions were always borne out by proving-ground experience.

One attempt was made to measure the effect of spin on the drag of a projectile. A model with a built-in motor was mounted in the wind tunnel. Drag measurements at 20,000 r.p.m. were made. The results agreed with the proving-ground experience in showing this effect to be negligible. How spin influences lift was not determined.

F i n -Stabilized Projectiles.

The instability (tumbling) of a projectile is usually avoided by "spin stabilization"; it may be equally well avoided by the use of a proper fin assembly on a non-rotating projectile. As will appear later, the latter procedure has several important advantages. The development of the fin-stabilized sub-caliber projectile,(the P.P.G.- "Peenemünde Pfeil Geschoss") for the K-5 (28cm) gun appears to be one of the most significant artillery developments of the present war. It was achieved largely by a group interested in aerodynamics, with little or no encouragement from those interested in the conventional rotating projectiles. The evolution of the P.P.G. is worth examining in some detail.

Fig.1 shows how fin stabilization is achieved. In the absence of the fin assembly, the aerodynamic forces in front of the center of gravity act upward; those behind it, downward. Both sets of forces tend to produce clockwise rotation about the center of gravity, which tends to increase α, the angle of attack, and makes the projectile unstable. With the fin assembly added, the forces behind the center of gravity tend to decrease α, and this stabilizes the projectile.

The first fin-stabilized supersonic projectile was made by Röchling in the spring of 1940 (Fig.2). The flexible fins proved too fragile and they were aerodynamically unsound.

The Peenemünde wind tunnel group (especially Drs. Hermann and Kurzweg, and Ing. Gessner) became interested in fin-stabilized projectiles upon the appearance of the Röchling type. They concluded, however, that the fin stabilization could not be satisfactorily accomplished if the diameter of the fins did not exceed the maximum diameter of the projectile; and this discovery meant that the projectile would have to be sub-caliber. Furthur, the force distribution leading to stabilization (Fig.1) could not be obtained with reasonably sized fins unless the fin assembly was at the rear of the projectile. Finally, in the initial designs, the aim was to maintain the mass-ratio unity. (which means that fin-stabilized and spin-stabilized projectiles were to be of equal mass) This mass-ratio can be obtained in a sub-caliber projectile only by making this projectile longer than the spin-stabilized. These general ideas guided the development of the P.P.G. through the four stages shown in the figures. A few facts about each type are given below.

Stage 1. Fin-Stabilized Projectiles with Sliding Fin Assembly. (Fig.3) (1940)

This type of projectile (max. diameter 5 cm.) had a range of 13 km as compared with 10 km. for the spin-stabilized projectile (caliber 7.5 cm.) of the same mass. Nevertheless, the design was abandoned in favor of one with no moving parts.

The projectile is impelled forward by pressure of the gases on the driving disk. It is guided in the tube by the guiding fing. Ring and disk are discarded during flight; these slower-moving parts may injure friendly troops.

This experience with this projectile proved for the first time that it is possible - on the basis of wind-tunnel measurements alone- to design a satisfactory fin-stabilized missile that will meet all aerodynamic requirements.

Stage 2. Plug-driven Projectile. (Fig. 4 & 5)

(Winter of 1940; first trial shot,May 1941) In this intermediate stage, the driving plug was introduced to transmit the pressure to the body of the projectile without damaging the fin assembly. The driving plug was 18% as heavy as the projectile, which means that considerable energy was wasted in accelerating it, also the flying plug was an unpredictable hazard and the fins were too fragile. Ways of combining the plug with the projectile were consequently sought.

Stage 3. Fin-driven Projectile. (Figs. 6,7,8,10)

(Trial shot, summer 1942) It had become obvious that the fin-stabilized projectile was best suited to large calibers and long ranges. The group therefore suggested that such a projectile be developed for the K-5 (28 cm.) gun. Wind tunnel data (3-component measurements, measurements of the pressure distribution and of the damping moment, see Fig.6), indicated that an 18 cm. fin-stabilized projectile for K-5 should have a range of 90 km, as compared with km for the spin-stabilized projectile of equal mass (see Fig.7). The 90 km range was xxxxxxxx actually obtained on the first shot, a remarkable result.

A fifth stage in the development of the P.P.G. was to be introduction of a metal "star" (discarded in flight) to protect the fins of the band-driven projectile. A fin-stabilized projectile of mass ratio 1/2 and 250 km. range for the 52 cm. Krupp tube was also planned. The size of the gun that can be built seems to be the only limit to the size of a fin-stabilized projectile.

Advantages and Disadvantages of Fin Stabilization:

(1) All the advantages (such as ease of manufacture) of a smooth bore.
(2) Sharply reduced wear of the tube (some of the tubes used for band-driven projectiles actually decreased in diameter owing to the deposition of iron from the riders on the fins).
(3) Greater range and or penetration
(4) The same gun can be used for projectiles of different calibers (or mass ratios) since all the projectiles are sub-caliber.

At the present time, the principle disadvantages are (1) too great a dispersion in range, which could probably be corrected and (2) the hazard from the discarded fragments of the driving band (of no omportance in naval gunnery)

H.A! Liebhafsky
June 21, 194[illegible]

The transition to a K-5 projectile brought with it the abandoment of the driving plug. The problem of incorporating the driving plug into the projectile without moving the center of gravity too far rearward was solved by strengthening the fins so that these could transmit the pressure of the gases through the driving disk. The projectiles were fired from rifled and smooth bore tubes. To fire them from the rifled barrel (an emergency measure), a special rotating disk was attached to the rear of the projectile, which then either did not rotate, or rotated very little.)

Stage 4. Band-driven Projectile.(Fig.9) (1943)

The projectile cannot be lengthened to more than 15 or 16 calibers if it is driven from the rear because the metal is not strong enough. Accordingly, the next development of the P.P.G. saw a driving band placed near the center of the projectile; this band also guided it.

Fig. 10 shows this type projectile in the caliber (10.9 cm) intended for A.A. use, but never introduced operationally. Because its time of flight would have been only 1/4 of that for the usual projectile, its introduction should have increased the probability of hits 64-fold.

The K-5 projectile of this type is believed to have been fired on Liege toward the close of the war. It was originally intended for use against England, wherefore it was necessary to build it with mass ratio 1/2 in order that the range might be increased from 90 to 130 km. As in the previous case, the range calculated from wind tunnel data (130) was actually obtained. Some 130 of these projectiles were fired last winter on the proving grounds at Rügenwalde under the supervision of Wa Prüf 1. (Some of these projectiles probably fell into Russian hands.) The dispersion in range was high, but the dispersion in deflection was less than that of the spin-stabilized K-5 shell. No data from the front are available; the 200 or so projectiles fired there were experimental models; there should have been 6 months more of development.

Riders made of soft iron were used to protect the fins of the band-driven projectiles.

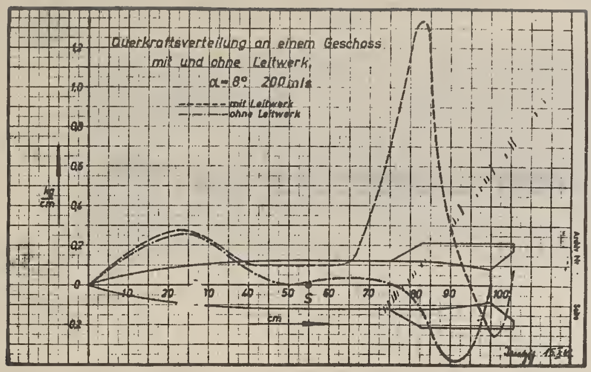
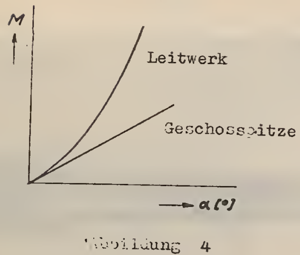


Fig. 1

Principle of fin stabilization



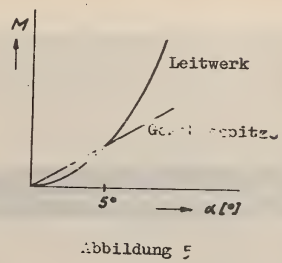


Fig. 1a

Moments and angle of attack for a completely stabilized projectile.

Fig. 1b

Moments and angle of attack for an incompletely stabilized projectile.

(For further discussion of the cases in Figs. 1a and b, see Ref. 3)

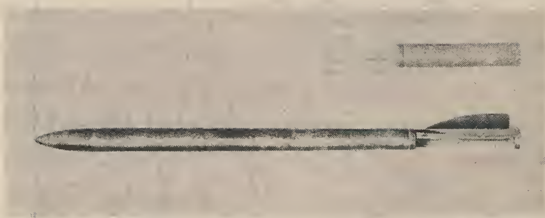


Fig. 2

Model of the first fin-stabilized projectile, the Röchling.
(Note the inverted cover for the fins, which is discarded)

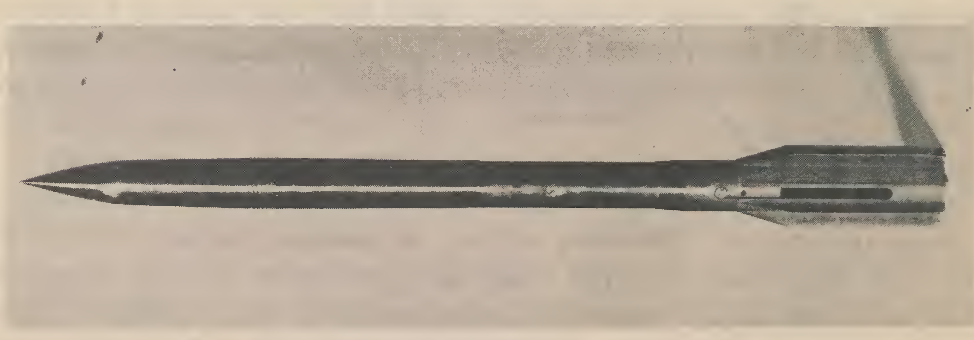


Fig. 3

P.P.G. Stage 1 (Sliding Fin Assembly)

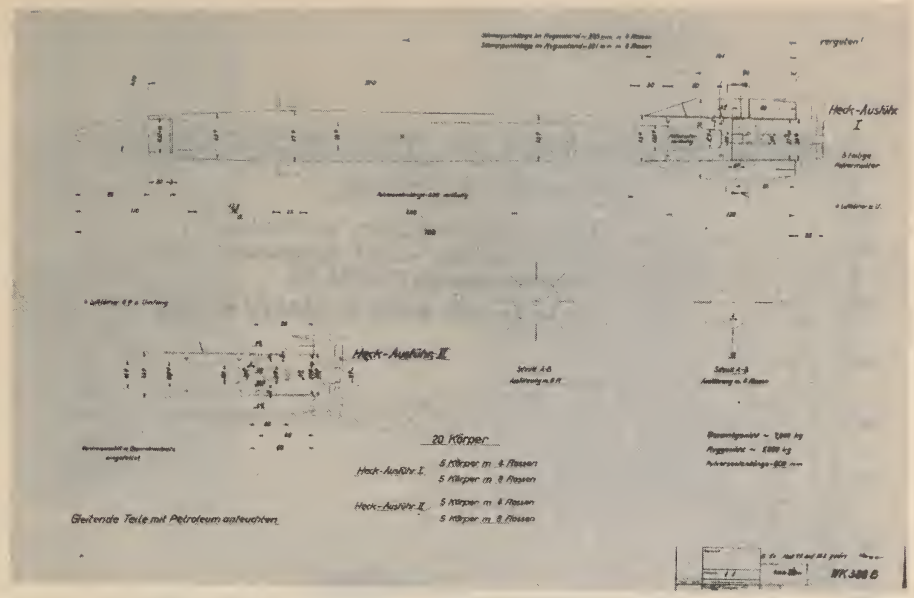


Fig. 4
Section of P.P.G. Stage 2 (Plug-driven)

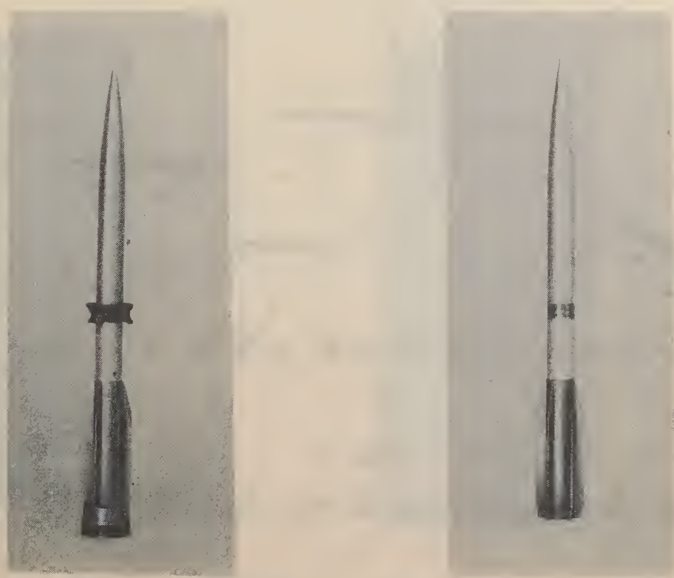


Fig. 5
Model of P.P.G. Stage 2. As stored (left; in flight (right)

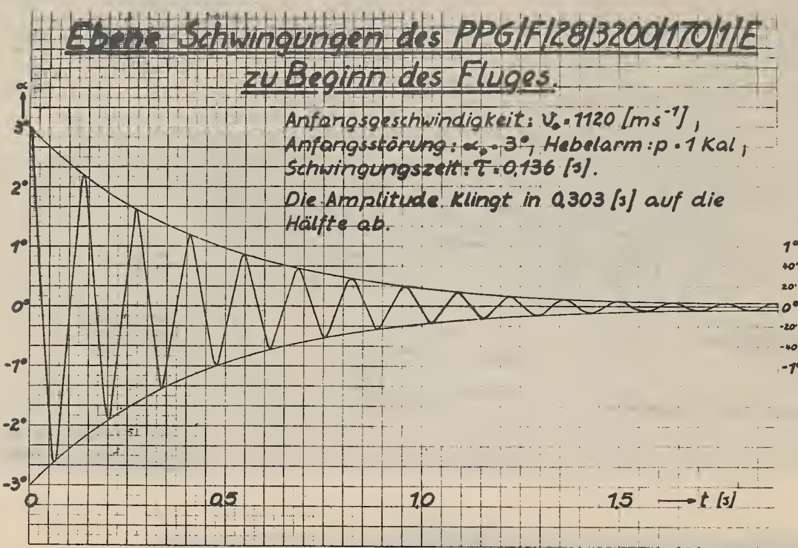


Fig. 6

Oscillation diagram for P.P.G. Stage 3.

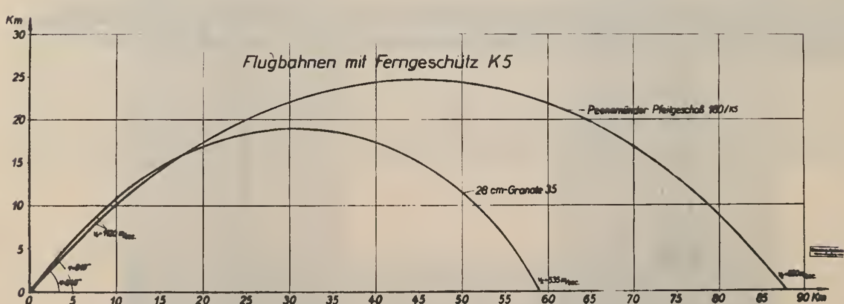


Fig. 7

Calculated trajectories for 28 cm. shell and 18 cm. P.P.G.

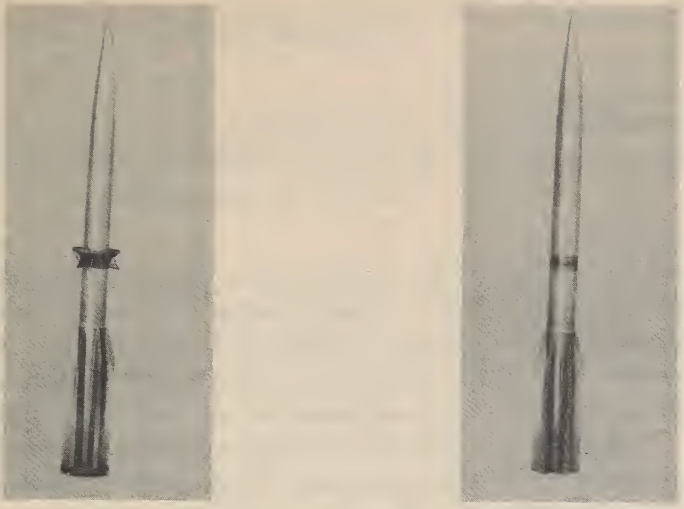


Fig. 8

Model of P.P.G. Stage 3 (Fin-driven). As stored (left): in flight (right)

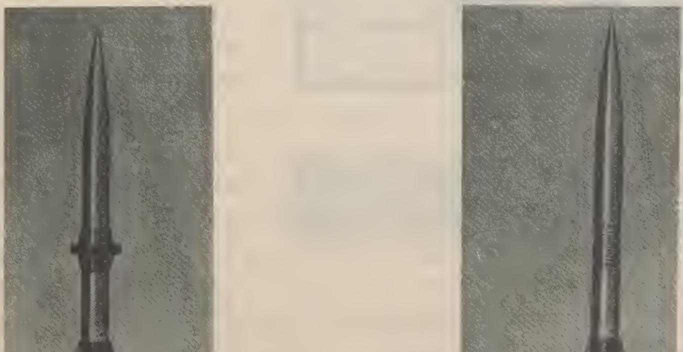


Fig. 9

Model of P.P.G. Stage 4 (Band-driven). As stored (left): in flight (

Fig. 10

P.P.G. Stage 3

The Aerodynamic-ballistic Research Institute WVA Kochel in the Service of Aircraft Research.

by H. Kurzweg

A summary of all subsonic and supersonic investigations and measurements signific/ant for aircraft development that were carried out in the wind tunnel at Peenemünde and at Kochel.

I. The Problems.

Modern transport aircraft and bombers fly at speeds near half the speed of sound (Ma - 0.5). The aerodynamic fundamentals for these aircraft were established in wind tunnels usually of large cross-section but of low velocities. These velocities usually did not exceed 60 m/sec (that is, Ma - 0.2). Since air is incompressible at the low velocities, such wind tunnel results may be used for aircraft to Ma=0.5.

The development of more rapid craft requires wind tunnel investigations of compressible flow in the region up to the velocity of sound (Ma - 0.5 to - 1.0). Five or 10 years ago, the construction of wind tunnels with diameters of about 2 to 3 m. was begun for this velocity range. Consequently, the results of measurements in compressible flow on wing profiles, on rudders, on the occurrence of shock waves at profiles and tail sections have been available for several years (DVL, Berlin; LFA, Braunschweig). The need for good aerodynamic measurements in this velocity range is extraordinarily pressing at this time, and this is true of fundamental, as well as of applied research. The aerodynamic knowledge obtained from practical experience with speedy fighter planes is not yet very great. There is practically no such knowledge for the region Ma=0.8 to 1.0. It is extremely urgent that a thorough understanding of this region be obtained as rapidly as possible by means of systematic wind tunnel measurements.

Naturally, the aim of future aircraft development is the exceeding of the speed of sound. This problem became urgent when it became necessary to pursue and to hit bombers and speedy fighters with certainty. The design evolved aerodynamically by us at WVA for project "Wasserfall" represents the first supersonic aircraft for velocities up to Ma=3. Since the initial velocity of this missile is zero, measurements on models had to be made, not only in the velocity range where the air is compressible, but also in the supersonic region and in the very difficult transition region between them. All measurements from Ma=0.4 to 3.0 were made in the WVA wind tunnel. From this it is evident that this tunnel is well suited to the purposes of ballistics, but that is particularly well adopted to the making of measurements relating to bodies (with and without wings) that resemble both aircraft and projectiles. For the latter purpose, it was obvious that the subsonic region would require through investigation and extensive measurements up to the velocity of sound. The missile "Wasserfall", the first to be equipped with wings, flew satisfactorily (after several experimental specimens had been made) at velocities up to Ma=3; that is through the trans-sonic region in which serious difficulties had been expected. This project showed emphatically that it is urgently necessary to carry out farsighted aerodynamic investiagtions. For, at the time when "Wasserfall" was urgently needed - at the beginning of 1943 - the fundamental aerodynamic data for a supersonic missile were not available. These were obtained in about 1 year.

II. Type of Wind Tunnel.

The ideal tunnel would be capable of handling full-size replicas at the actual velocitites to be encountered. These requirements can scarcely be met today, because of the enormous costs entailed. For the lower (but not for the higher) speeds, it has proved possible to build tunnels of diameters 10 m and more. The Berlin and Braunschweig tunnels, which attain sonic velocity, are 2.7 m in diameter and, even at that, require 10,000 kw. Supersonic tunnels of such dimensions would presuppose enormous electrical capacities.

However, most aerodynamic investigations in the region where air is compressible, and in the supersonic, do not require wind tunnels of large cross-section. Sufficiently reliable results can be obtained on relatively small models, if only the required Ma values are reached in the tunnel. At high velocities, the Mach number is the principal parameter involved in transferring to the full-scale speciment results obtained on the model. The Reynolds number, which is important at the lower velocities, decreases in importance relative to the Mach number at velocities approaching and exceeding that of sound. It does play a role in investigations of surface friction and of boundary layers; but such investigations always require special apparatus. If the size of the model is such that the Reynolds number lies in a region above the laminar section of the the surface-friction curve, then the Mach number provides sufficient basis for assuming similarity of model and original under identical conditions of flow.

Since this requirement is met in the WVS wind tunnel with its 40 x 40 cm. cross-section, it is immediately possible to carry out in this tunnel all the aerodynamic measurements required. A lower limit beyond which measurements are not possible is fixed only when special investigations on the smallest parts (such as edges or supports) of the aggregate are required. Since, however, new projects require fundamental measurements on the body, wings, fins, rudder etc., the wind cansl in its present form is capable of handling all the fundamental work required for such projects in the near future. For subsequent aircraft development, a tunnel of about 1 x 1 m cross-section will have to be provided, which will at once facilitate measurements of the kind just described and make possible the attaining of very high Ma values.

It is very important to note that the forms of wings and control surfaces change radically as the speed of aircraft approaches or surpasses that of sound. The breadth of the aircraft decreases as its speed increases: in "Wasserfall", for example, the breadth of the wings is no greater than that of the stabilizing fins; that is, most of the wing span now lies within the direction of flow, not perpendicular to it. In the WVA tunnel we have carried out long series of measurements relating to the development of aerodynamic bodies, such as the bodies of projectiles or of rockets, and of aircraft hulls. Experience is available particularly on the effect of an emitted jet on flow around XXXXXXX an aerodynamic body in the sub - and supersonic regions. This experience relates principally to the not entirely simple experimental technique required in such investigations. In general, we have available measuring instruments and methods sufficient for the most rapid, the most practical, and the most precise investigations; in part, these are available only at our wind tunnel XXXXX (e.g., a null balance for measuring moments, an X-ray method for measuring densities;etc.)

XX In the following pages, there will be described individual investigations that may be regarded especially as investigations relating to the most rapid aircraft for the future.

III. Measurements Relating to the Most Rapid Aircraft.

(1). Constancy of the center of pressure XX for "Wasserfall".

Experience has shown that the center of pressure for an aerodynamic body depends upon the angle of attack and upon the velocity of the body. This applies to plates, profiles, hulls, etc. The migration of the center of pressure usually begins only when the speed has exceeded Ma=0.5. The migration is strongly dependent on the shape of the body. It may become appreciable as one passes from the sub- to the supersonic region. As this happens, the body may pass from stable to unstable equilibrium, or vice versa, depending upon the location of the center of gravity. This fact imposes special requirements upon the guiding of airdraft. In project "Wasserfall", for example, in which the quiding was to be mechanical, these requirements constituted one of the most important problems. The machine to do the steering was to be of the smallest power feasible; that is, the lever arm of the resultant of the aerodynamic forces was to be kept as small as possible during the entire flight. Aerodynamic measurements on "Wasserfall" as first designed (see fig. XX 1 a) showed that the center of pressure migrated by more than one diameter of the hull. With the center of gravity chosen, the model was unstable in the subsonic, stable in the supersonic region. This instability could have been avoided by displacing the center of gravity forward; but in the supersonic region, the center of pressure (Kurzweg has "center of gravity") would then have been so far back as to require a far more powerful steering madhine than specifications allowed.

By means of systematic distribution measurements over the entire urface of bodies with fin assemblies, it proved possible to determine the distribution of the aerodynamic forces over the entire surface for a wide range of velocities. Fig.2 shows several examples for the fin-stabilized rockets A-4 at sub- and supersonic speeds. By examining these, it is easy to see how the pressure distribution changes gradually as one passes from low speeds through the subsonic region where the air is compressible, and finally into the supersonic region.

Upon the basis of the investigations, the aerodynamic surfaces of "Wasserfall" were designed. Sufficinet constancy in the location of the center of pressure was achieved. Fig. 3 shows H/D (distance, in diameters of the hull, between the center of pressure and the tail) as a function of Ma. For comparison, a similar curve is given for the fin-stabilized A-4 (body with fin assembly only).

(2) The aerodynamic development of the glider aircraft A-4b (A-9).

The aim was to increasr the range of A-4 from 300 to approximately 480 km. There was the possibility of realizing this aim by changing the rocket "projectile" into a rocket "glider"; that is, the body of A-4 s to be equipped with wings. Approximatel calculations indicated a wing surface of 20 sq.m. The most favorable aerodynamic form was completedy unknown. The velocities during flight ranged, as in the case of "Wasserfall", from zero to several times sonic. The measurements were carried out from the following points of view:

(a) Attainment of the required lift with minimum drag at all speeds. To achieve this, the ratio of lift to drag was established by means of the 3-component balance for various types of wing and fin surfaces.

(b) Attainment of the most nearly invasiant location possible for the center of pressure.
The experience obtained on " Wasserfall" was available. Long series of measurements were carried out on many different ~~variation~~ variations of "arrow" wings and "trapeze" wings.

(c) Adaption of the aerodynamic requirements to the construction of the missile. Attainment of the simplist possible ~~projectile~~ profile without straak. Effect of this change in the profile on the ratio of lift to drag and on the position of the center of pressure.

Figs. 4 and 5 show the development of the wing. The investigations did not by any means lead to a completely satisfactory solution.

The migration of the center of pressure is lower for the "trapeze" wing than for the "arrow" wing, but it has not been completely avoided. The ratio of the lift to drag is satisfactory for the proposed range requirements.

The measurements of the moments and of the stability were made quickly and directly by means of a device, the so-called null balance for moments, which we constructed. With this arrangement, the stable equilibrium positions may be determined to within about 1/3 degree in the angle of attack; the unstable positions, to within about 2°.

(3) The Development of Aerodynamic Rudders.

In the region Ma=0.5, where the air is incompressible, the developement of rudders on the basis of the experience everywhere available presents no particular difficulty. As the speed increases, however, a migration of the center of pressure occurs also on the rudder surfaces; this migration is strongly dependent on form, on the profile, on the adherence of the stream to the fixed part of the fin assembly, on the formation of shock waves, on influences of the jet, etc.

We developed, in the WVA wind tunnel, the rudders for A4, which prevented the rolling of the rocket. Even though these "spin rudders" had an area of only about 1/2 sq. cm. on the A-4 model, we would measure satisfactorily on them the migration of the center of pressure, the hinge moments and the normal forces, as well as the resulting spin moments. These rudders served their purpose satisfactorily on the full-scale rocket.

A further extensive series of measurements was carried out in the aerodynamic rudder for "Wasserfall". The aim in this case was to achieve a rudder whose center of pressure remained as nearly fixed as possible over the entire range of velocities. With the rudders of conventional for, a pronounced difference in centers of presure for the subsonic and for the supersonic region always exists, and no method of compensation, no matter how devised, can prevent it. If one places the axis of the rudder very far forward, and slopes the portion of the rudder lying in the free stream strongly toward the rear, then one does achieve a sudden stable at all speeds; but the hinge moment of such a rudder in the supersonic region will be prohibitively large. Fig. 6 shows rudders with differing characteristic moment curves; these are stable in the supersonic but unstable in the subsonic range. The rudder R 12 was beyond the capacity of the projected guiding machine, But rudder R 21 could be operated by the machine.

On the other hand, rudder forms that do not have negative tangents to thier momentum curves at any velocity were attained as a consequence of systematic measurements of pressure distribution and of moment.

These rudders, which have a slit at XX a certain place, are still in the initail stages of development.

(4) Development of Aerodynamic Rudders with Auxiliary Rudders.

In order to accomplish the same purpose - namely, to avoid large hinge moments in the rudders, the development of auxiliary rudders was undertaken. We have carried out several series of experiments in the subsonic region where air is compressible, and in the supersonic region, on auxiliary rudders of different forms. Further measurements were in prospect. The chances of obtaining favorable results are good.

(5) Fundamental Measurements of the Center of Pressure on Profile Plates.

Plane and profile plates were investigated in order to establish the fundamentals governing the migration of the center of pressure on wings and fins as caused solely by the increase of velocity in the subsonic region where air is compressible, and in the supersonic region. The aspect ratio was approximately 2:3 (greatest extension in the direction of flow). Several of these interesting results are given in Figs 7-9. Centers of pressure near half the length were obtained neither with parallel nor with profile plates; this result is in accord with the theory for small aspect ratios. These measurements were carried out by a special method. The plates were made as so-called half-models, the axes of rotation being taken through th tunnel walls so that the moments could be determined by external loading. The method is extraordinarily rapid and reliable.

(6) Important X-ray and Interferometric Measurements.

As an addition to the other well known methods, we developed XXX an X-ray method of measuring the density of the flowing air in the sub and supersonic regions. It is possible by this method to make the most precise measurements at the surfaces of wings and aerodynamic bodies (2 and 3 dimensional models), and thus to determine the pressure distribution without the use of a material probe. Fig. 10 shows the first application of this method, the measurements being made near the vertex of a conically shaped profile. The results show the density changes ahead of and behind the shock wave. One sees that the experimental method gives a result in good agreement with the theoretical value.

The interferometer also provides a way of avoiding the use of a material probe in the making of density measurements; we have an interferometer available for this purpose. Fig. 11, which shows a 3-dimensional case (accone, the vertex of a pointed tail), may be cited as an example. The evaluation of the interferometric results will be very simple once the integrator developed in the WVA is finished.

(7) Heating of the Skin of Aerodynamic Bodies During Flight at Speeds at which Air is compressible.

With present aircraft, one does not need to be concerned about the heating of the skin (and hence of the entire body) during flight. XXXXa

Since the impact temperature of the boundary layer, which is fixed by the friction and the impact of the air, at the surface increases with the square of the speed, this matter must be considered for aircraft flying even at the velocity of sound; at 330 m/sec, a temperature increase of about 50°C. occurs. For example, in the supersonic aircraft "Wasserfall", the maximum temperature of the boundary layer during flight does reach 215° C. Fig. 12 shows steel sheet temperatures calculated from the heat transfer coefficients determined in the wind tunnel.

General report of Kochel Wind Tunnel

The Supersonic Wind Tunnel of the Heereswaffenamt (Peenemünde–Kochel) and its Application in External Ballistics.

By Dr Rudolf Hermann

Translator's Preface.

A 2-volume treatise on internal and external ballistics by German experts, civilian and military, was planned in honor of the 60 th birthday (1939) of General Becker, who was chief of the Heereswaffenamt, dean of the military technical faculty at the Technische Hochschule, Berlin, etc. The following material on the supersonic wind tunnel, by Dr. R. Hermann, was intended to be a part of this treatise. As General Becker died before the treatise could be published, it was planned to issue the material as a memorial volume, which gave Dr. Hermann opportunity for a revision that made his contribution up-to-date as of December, 1940. Two or three galley proofs of this contribution were made. It was finally decided not to issue the treatise for reasons of security, with the result that the bound galley proofs, from which the present translation was made, constitute the only copy in existence of Dr. Hermann's contribution.

The first part of the translated material describes the Peenemünde supersonic wind tunnel and the experimental methods used in connection with it. Most of this part is still up-to-date; since 1940, however a silica gel drying installation has been added, and additional experimental methods (e.g., X-ray and interferometric) introduced. All in all, this wind tunnel is the most powerful and the best equipped in Germany

The high Mach number attainable in the tunnel [illegible] it was intended primarily for the study of [illegible] projectiles) rather than of conventional aircraft. [illegible] part of Dr. Hermann's book lays the foundation for [illegible]ation of missiles and gives the early experimental [illegible] though the extensive subsequent work has dated some of the [illegible]rial, this section of the book is still a good [illegible] this important field.

The translator is a member of C.I.O.S. Team [illegible], which [illegible]vestigated this target and whose report should be consulted [illegible] the more recent information. The translation, though [illegible] done, should be reasonably correct since it was checked with Dr. Hermann and his co-workers. "Heereswaffenamt" has been [illegible]ly translated; it was not the German War Ministry, [illegible] responsible, under the OKH for military research and for the development of new weapons and other military equipment. Finally, Fig. 57, which was not in Dr. Hermann's book, has been added here to show more clearly how the model is mounted in the tunnel.

H.A. Liebhafsky

Kochel, Germany, 16 June 1945.

The Supersonic Wind Tunnel of the War Ministry and its Application in External Ballistics.

By Rudolf Hermann, Berlin,
with 56 illustrations.

Translator's Note: All of the important sections of the book will be freely translated H.A.L.

Introduction (p 1-3)

In the last 30 years, the wind tunnel has become a valuable experimental tool for aeronautical research, and it is therefore natural to use this tool for studying external ballistics. In the wind tunnel, it is possible to measure the magnitude and direction of the forces and moments acting on the projectile under various experimental conditions: this cannot be done on the proving ground. Wind tunnel and proving ground will supplement each other in revealing the fundamentals of external ballistics.

The domain of external ballistics now includes not only the further development of the usual spin-stabilized projectiles, but also the development of non-rotating missiles, stabilized with fins ("arrow-stabilized") and flying with supersonic velocities. It is worth mentioning that experimental results obtained in the wind tunnel may be applied most readily to non-rotating projectiles, for the presence of spin complicates matters because of the interaction of aerodynamic and gyroscopic forces.

Extensive wind-tunnel measurements have not been made for the purposes of external ballistics, partly because measurements at subsonic speeds do not suffice and the necessary supersonic facilities were not available. At the time the present tunnel was planned, there were in Germany the following supersonic installations: Göttingen (6 x 6,7 cm) and Aachen (10 x 10 cm; and 20 x 20 cm).

The Supersonic Wind Tunnel of the War Ministry.

I. Fundamental Considerations.

1. The Wind Tunnel Principle in General.

In actual practice, a flying body moves through the air; in the wind tunnel, the air moves past the clamped model. The wind-tunnel results are trustworthy only if the air stream is parallel and of constant velocity over its entire cross section and along the entire length of the model. The realization of these conditions depends upon the quality of the nozzles. Because of the nature of the laws governing supersonic flow, each disturbance in the gas stream is propagated downstream with undiminished intensity. This makes the obtaining of good experimental conditions very difficult. Furthermore, each supersonic velocity requires a nozzle of different shape; the designing and making of such nozzles is one of the crucial problems in wind-tunnel construction.

In order to translate wind-tunnel results to actuality, certain rules regarding the models must be observed. At velocities below 100 m/sec., the air is practically incompressible, and the most important rule is that the Reynolds numbers must be identical in the wind-tunnel and in practice. At supersonic velocities, the importance of the Reynolds number decreases, and the most important rule is that the Mach number $Ma = {}^{v}/a$ must be the same in the two cases. (v = velocity in the tunnel, a = velocity of sound under the conditions in question).

2. Requirements for the Wind Tunnel.

At the present time, the upper limit of velocities for projectile development lies at about 1200 m/sec. Higher velocities would be desirable in the tunnel for experimental purpose.

The requirements for the present tunnel accordingly call for the highest attainable Mach numbers. With the Aachen experience to build on, the attaining of Ma = 3 in the present tunnel was assured, and higher values could probably be attained upon further development.

A supplementary requirement was the rapid completion of the tunnel. Since the taking of many data was planned from the first, every effort was made to build the installation so that long series of measurements could be carried out rapidly.

3. Choice of the Type of Tunnel.

The following types of tunnels are known:

a) Closed-cycle Tunnel.
The closed tunnel in which the air is continusously circulated

by blowers is customary for low velocities (up to 50 m/sec) concerned in many aircraft applications. The first supersonic tunnel of this type was built by Ackeret in Zürich. A similar one has been built in Guidonia. The advantage of this type is that of a closed system: the air is easy to keep dry, and other gases may be used, the latter point being of importance in experiments intended for great altitudes (50-100 km), where the composition of the air has changed. There are the following disadvantages. The blower system must have many stages and be flexible enough to meet wind-tunnel requirements; such an installation would have been slow to build. Further, very little was known in detail about how a gas stream behaves in such a tunnel. For example, it was not certain how much of the kinetic energy of the stream could be reconverted into pressure energy after the stream had passed the measuring chamber. And finally, Ackeret reached only Ma = 2.5 in his tunnel; it was not possible to predict how much more development would be required to attain higher velocities. The closed cycle tunnel could not meet the requirements in the present case.

b) Open Tunnel.

In open tunnels, a vacuum pump system sucks air through the measuring chamber and then exhausts into the atmosphere. The power available is a decisive factor, for the power required for a supersonic wind tunnel is of a higher order of magnitude than that for the usual tunnel intended for aircraft applications: cross-section of the stream and air density being constant, the power required increases as the cube of the velocity - a 40 x 40 cm cross section would require a pumping station of about 4000 Kw. Such a station was not available, and it was consequently necessary to design the present canal for intermittent operation, thus following the example set by Prandtl in Göttingen.

An intermittent wind tunnel, 40 x 40 cm, can be built with 800 Kw available. Furthermore, the experience with the two Aachen supersonic intermittent tunnels was directly applicable. This experience included the flow-determining properties of the tunnel, the characteristics of the vacuum pumps, and the constructional details of the measuring chamber. The sole drawback was that air only could be used; the disturbing influence of water was removed by drying the air in a specially developed installation.

4. Operation of the Supersonic Wind Tunnel.

a) Operating Principles of the Entire System.

Fig. 1 is a schematic diagram of the wind tunnel installation a planned. The 40 x 40 cm intermittent tunnel is operating; the 20 x 20 cm continuous tunnel is under construction.

The intermittent operation of the 40 x 40 cm wind tunnel proceeds as follows. The rapidly acting valve between the vacuum reservoir and the measuring chamber is closed so that the pumps which run continuously and exhaust into the atmosphere, can evacuate the former. After the vacuum necessary for the particular run has been reached (approximately, 90 % vacuum for Ma = 1.5, and 98 % for Ma = 3), this valve is opened; air then streams through the measuring chamber into the reservoir. By means of the displaceable diffuser, which will be described later, it is possible to maintain the velocity of the gas stream strictly constant for a definite time, even through the pressure in the reservoir increases. During this time, which ranges from 18 to 20 sec., depending upon the velocity of the air, the measurements on the model are carried out in the measuring chamber. Thereafter the rapidly acting valve is closed, and the pumps proceed to evacuate the reservoir anew. Since the reservoir is only half-filled in the course of an experiment, subsequent evacuations after the first are more rapid; they take only 3 to 5 minutes depending upon the vacuum required.

b) Building Plan.

It is obvious from Fig. 1 that there are three main parts: the experimental room, which houses the tunnels; the reservoir room; and the pump room. Sound-proofing is desirable . The ports at which the air enters the tunnels are protected by concrete structures so as to reduce the effect of the weather on the incoming air. The rest of the text at this point is fairly obvious from Fig. 1.

c) The Special Processes in the Measuring Section.

Fig. 2 is a schematic diagram of the supersonic tunnel and it shows the sections (described below) through which the air passes from right to left when the rapidly acting valve (SSS = Schnellschluss-Schieber") is opened after evacuation of the reservoir. Fig 3 is a picture of the measuring chamber; here the air flows from left to right; the glass wall of the measuring chamber (center) is open; the displaceable diffuser (Verstell-Diffusor) is on the right; at the left is the carriage for the Schlieren apparatus.

<u>The suction funnel</u> has a large opening so that the entering air moves at low velocity, thus avoiding both turbulence at the walls and the sucking in of foreign bodies. A "collimator" (to insure parallel air flow) is part of the suction funnel.

<u>The measuring chamber</u> contains the model and the three-component balance by means of which the forces on the model are measured. A parallel air stream of supersonic velocity is generated by the Laval nozzle. This stream flows freely to the end of the chamber and is then gradually converged by the displaceable diffuser with minimum energy loss.

<u>The displaceable diffuser</u> enables one, by displacing two flexible steel sheets, to alter the cross section of the air stream continuously at will. The position of the diffuser in Fig. 2 is that for normal operation. The displaceable diffuser must accomplish these objects: it must make possible the establishment in the chamber of the pressure corresponding to the various Ma values; and it must make possible the maintaining of this pressure strictly constant even though the pressure in the reservoir is increasing during the run. This second function is indispensable to successful operation of an intermittent tunnel; the decrease in velocity that would otherwise occur in the measuring chamber could not be tolerated. The flow in the converging section of the diffuser is governed by the boundary layer of the "recaptured" supersonic stream that had moved freely through the measuring chamber. In the diverging section, a change from supersonic to subsonic flow takes place through the occurence of a shock wave.

<u>Transition section.</u> The measuring chamber is made rectangular because the theory of supersonic flow (according to which the Laval nozzle must be designed) is known only for the two dimensional case, and because glass plates must inclose the Laval nozzle if Schlieren photographs are to be taken. The displaceable diffuser must be rectangular for constructional reasons.

In the transition section, the cross section of the tunnel changes from rectangular to circular at the SSS.

SSS. The rapidly acting valve (SSS) must open rapidly at the beginning of a run so as to make the entire cross section of the tunnel available as soon as possible, and it must close rapidly when the run is over so that air does not stream unnecessarily into the reservoir.

The Divergent Section is a conic whose diameter increases from 600 to 1200 mm. Toward the end of a run, there is subsonic flow in this section. The gradual divergence is responsible for the good reconversion of kinetic into pressure energy; if this section functions satisfactorily, the time available for a good run will be lengthened.

The Compensator (Sylphon Bellows) between the divergent section and the vacuum reservoir is inserted to take up changes in length caused by pressure and temperature differences.

5. Choice of the Fundamental Dimensions and Power Plant.

a) Cross sectional area.

The cross section of the gas stream is the fundamental parameter that determines the size of the wind tunnel and of the power plant, and hence the cost of the entire installation. This cross section is in turn fixed by the maximum size model to be investigated. In supersonic tunnels, the maximum length of the model is restricted by the requirement that the head wave (the shock wave formed at the forward tip does not strike any portion of the model after being reflected from the walls. At Mach = 1.4, this maximum length is approximately equal to the diameter of the stream. At higher Mach numbers, the model may be longer because the angle enclosed by the shock wave is more acute; for lower Ma values, the reverse is true. At the sonic velocity, measurements free of all possible objections cannot be carried out in any wind tunnel, no matter how it is built, for at that velocity the shock waves are perpendicular to the direction of the gas stream so that they must strike the model after being reflected from the walls of the tunnel.

In order to obtain precise measurements of the forces acting on the smallest parts (e.g., stabilizing vanes) of the model, it is desirable to have the model as large as possible. Furthermore, the model must be large enough to permit the drilling of enough holes and the attaching of enough leads to measure the pressure distribution, and the installing of thermocouples in sufficient number. Also, precise construction is easier to attain with large models. Since large models require large wind tunnels (and, hence, large resources for building), it is obvious that the cross section of tunnel finally decided upon must be a compromise between technical requirements and resources available. The cross section 40 x 40 cm was chosen so that models roughly 40 cm long could be studied at Ma values of 1.4 and above.

b) Vacuum reservoir.

Once the cross section is fixed, then the size of the vacuum reservoir is determined by the length of run desired; that is, by the length of time during which the velocity of the gas stream remains absolutely constant.

The shorter the time in which a measurement can be made, the smaller the vacuum reservoir required. In order to shorten this time, an electromagnetic balance was built such that a "three-component" measurement (lift, drag, pitch) could be carried out in 8 - 10 sec. If necessary, the results can be recorded on an oscillograph. In order to have enough latitude even in the case of difficult measurements, the time of a run was chosen as 18 to 20 sec. After due consideration of the conversion of kinetic to pressure energy at these values, and of the heat generated in the vacuum reservoir by the gas as it enters, a reservoir of 1000 m^3 (diameter 12.5 m) was chosen. This choice permits 18 to 20-second runs at Ma = 1 to 3.

c) Vacuum pumps.

With the cross section of the stream and the size of the reservoir fixed, the pumping capacity required depends upon how short the interval between the 20-second runs is to be. This interval must be chosen with the efficient utilization of the entire installation in mind. There is no point in having pumps powerful enough to complete the evacuation of the reservoir in less time than is required to prepare the wind tunnel for the next run and to record the results of the last. Three to six minutes seemed a reasonable interval to select, and this required a pumping speed of roughly 45000 m^3/hr., and power to the extent of 800 kW

If only a three-component measurement is to be made, the time of a run may be shortened to 10 sec., and the interval between runs to 1.5 to 2 minutes.

d) Wind Tunnel for Continuous Operation.

The pumps having been selected for intermitted operation (a-c above), it is of interest to ask how large a wind tunnel could be operated continuously by these pumps at Ma values up to 3. Upon considering the variable performance of the tunnel in this range and the variable capacity of the pumps at the various pressures, one arrives at 20 x 20 cm as the cross section of such a tunnel, in which models up to 20 cm long could be studied. For the study of heat transfer relationships (e.g. in the skin of projectiles) a continuously operating wind tunnel is particularly useful. Consequently a 10 x 10 cm continuous tunnel was planned from the first. This tunnel was to be coupled to the same vacuum reservoir, which, in the case of continuous operation, will serve only as a buffer to smooth out irregular pump performance.

II. Description of the Wind Tunnel Installation.

1. Vacuum Pumps.

As stated in Section I, it is necessary to complete 98 % evacuation of the 1000 m^3 reservoir in order to maintain Ma = 3 in the wind tunnel for 20 sec. The air streaming through the measuring chamber in the course of a run reduces the vacuum in the reservoir so that values ranging from 50 to 85 % vacuum are reached at the end of a run. The pumping installation must be meet the following requirements:

1.) Evacuation of the reservoir to 98 % vacuum.
2.) A pumping time of about 5 min. between runs.
3.) Highly dependable operation.

These requirements were met by selecting 6 conventional rotary compressors as the pumps. These are divided into 3 units of one pair, each pair being driven by a common motor. Initially, the three units operate as 6 single-stage compressors. Beyond 90 % vacuum, the pump performance drops rapidly; consequently, the hook-up of the pumps is changed at that point so that 2 pairs of pumps operate as a low-pressure stage in series with the third as a high pressure stage. The division of the pumping installation into several units makes for dependable operation since operation of the tunnel can be continued in the event of a pump or motor failure. This arrangement does lengthen the time between runs. The total pumping speed is 44400 m^3/hr (7400 m^3/hr per pump). Because of the unavoidably imperfect sealing in the pumps, the performance (ratio of the volume of air actually displaced to the volume displaced by the pumps) is always less than 1, and sinks strongly at low pressures (fig. 4), as the following pumping speeds show: with single stage operation, 36,400 m^3/hr at 60 % vacuum and 29,600 m^3/hr at 90 % vacuum; with two-stage operation, 25,200 m^3/hr at 90 % vacuum and 24,200 m^3/hr at 95 % vacuum. The drop in performance at low pressures is relatively small in the latter as compared with the fomer hook-up. The following table gives the times required to attain definite pressures with the two hook-ups; the data for the two-stage operation begin at 60 % vacuum because pre-evacuation is necessary with this hook-up.

Time to Reach a Definite Vacuum.

% Vacuum	Single stage (min.)	Double stage (min.)
10	0.14	
20	0.30	
30	0.50	
40	0.75	
50	1.05	
60	1.42	0.00
70	1.96	0.49
80	2.87	1.25
90	4.71	2.93
95		4.93
98		8.01

The table shows that 50 % vacuum is reached in a minute. So far as the time schedule of runs is concerned, it consequently does not matter whether the vacuum in the reservoir is 50 % or 30 % at the end of a run.

The pumps are driven by motors each of which has a 270 kW rating at 6000 volts, which makes the total power requirement 810 kW. The pumps are mounted so as to damp out vibrations that might otherwise affect the building, and be carried over to the measuring chamber.

2. Controls.

As Fig. 5 shows, a shut-off valve and a two-way valve are necessary to change the pumps from series (single stage) to parallel (double stage) operation. These two valves are electrically driven since they have to be operated often and rapidly. Two manual valves are introduced in front of Pump Units 2 and 3, which always operate as low pressure stages, in order to permit isolation of a unit during a breakdown. Finally, a throttle had to be inserted in the line to the vacuum reservoir to avoid undesirable pressures in the line between the high and low pressure stages; such pressures might occur during two-stage operation if the reservoir fills rapidly. A sound absorber is installed in front of, and another behind each pair of pumps. Each pair of pumps is protected by an air filter. The oil evaporating at the high pressure side is taken out to a large extent by a trap. The installation is flexible enough so that it may be adapted to changing experimental conditions.

3. Vacuum Reservoir.

The walls of the reservoir tend to suck in. Because the load in a spherical reservoir is uniformly distributed, such a reservoir is less subject to this difficulty than a cylindrical one would be. A spherical reservoir, internally strengthened to give rigidity, was selected; this type of construction tends to prevent small deformations that might give rise to sucking-in. In this way, it was possible to keep the wall thickness down to 17 mm. In order to make the reservoir vacuum-tight, the sheets were butted together with inner and outer reinforcing strips, the whole being riveted tight with double rivets. A vacuum test with soap bubbles showed that only 2 of the 13,000 rivets leaked. All rivets and overlaps were forced together. To facilitate continuous observation of the reservoir, a movable ladder that can traverse the equator of the reservoir was installed. Sylphon bellows to take up expansions and contractions due to temperature or pressure differences are installed at the entrance and exit to the reservoir; these could permit movements of several inches without puting a strain on the pipes.

4. Rapidly-acting valve ("Schnellschluß-Schieber" abbr. SSS)

In order to utilize all the time of a 20-second blast in the tunnel, it was necessary to insert between reservoir and measuring chamber a rapidly acting valve that would make the entire cross section of the tunnel accessible to gas flow within 1 or 2 seconds. The conditions peculiar to the supersonic region further require that the open valve permit undisturbed flow of the gas; i.e., that no shock waves are formed. And the valve must be tight when closed. It was built as a rotary valve, as a simple stopcock. The valve executes rotary motion for opening and closing; and vertical motion to prevent leaks, the male member being dropped to seat it when the valve is closed. The drive is electric. The forces exerted by the air on the male member are extraordinarily strong during the opening and closing of the valve. Their magnitude could be gauged only after the operation of the installation had begun, so that the drive required for the rotation had to be determined by actual trial. The time for opening (and for closing) is 1.2 sec. A suitable electrical braking mechanism insures that the valve is nevertheless seated so gently as not to shake the measuring chamber or the optical installation.

5. Remote Control and Switchboard.

Since the whole installation is very extensive, remote control of the machines and valves from near the measuring chamber was necessary. By means of the remote control panel, it is possible to control each part of the installation independently. On the other hand, a fixed control is provided by means of which the change from parallel to series pumping - the most important change in normal operation - or its reserve, can be accomplished by a single operation (by pressing a button). In order to provide an instantaneous picture of the installation in operation, a lighted diagram on the central control board in the laboratory shows the position of all the valves and of the throttle on the vacuum reservoir, and shows also whether the machines are operating properly. Apart from this, there are special automatic safety measures for the pumps, which are particularly susceptible to trouble.

These automatic safety devices control the temperature of the exit air, the pressure of the exit air, the flow of cooling water, and the pressure in the line connecting the high and low pressure stages in series operation of the pumps. In all cases, the machine concerned is automatically shut down in case of improper operation

XII. The Measuring Equipment of the Wind Tunnel.

1. The measuring chamber and the three-component balance.

The measuring chamber with the three-component balance and the displaceable diffuser are the most important parts of the experimental section of the wind tunnel. The structure of the measuring chamber is fixed by the following requirements (see Figs. 2 and 3): It must contain the Laval nozzle. Ready operation of the tunnel requires an easy interchange of the nozzle necessary for different Ma values; this was attained by making a special foundation for the nozzles. Furthermore, the model must be in the chamber. The forces acting on the model have to be transmitted to the three-component balance by suitable intermediary members (see Fig. 6); the balance itself is installed above and below the air stream in the measuring chamber. Four large glass planes afford an unobstructed horizontal view into the chamber. The two inner panes are the sides of the Laval nozzle; and the two outer panes are the sides of the measuring chamber itself. In this way, it is possible to observe simultaneously (Schlieren apparatus) the flow through the nozzle and the flow around the model. Because the panes were so large and carried a heavy pressure load, safety glass strongly resistant to bending was used, but this was not satisfactory optically. It was therefore replaced by thick-walled plate glass, plane-parallel pieces of the best optical quality being required. The three-component spring balance with electromagnetic registration is shown in Fig. 6; changes in the inductances of choke coils are measured in a bridge. The three components measured are lift and two drag components from which the total drag can be obtained (by addition) and the pitching moment (by subtraction). All parts of the balance are in the air-tight measuring chamber.

Cables lead from the chamber to the externally located electrical instruments. By simply changing the electrical hookup, 4 regions of different sensitivity may be obtained between 2 and 18 Kg. In the mechanical construction of the balance, it is important that all levers, bearings, knife edges and pans be replaced by flat springs and steel strips, which gives great sensitivity and precision along with robust construction. The precision of the balance is 0.3 % of the maximum value; a change of 5 g can be detected in the most sensitive region. This sensitivity satisfies aerodynamic requirements, and it is note-worthy because the balance is violently shaken owing to shock waves and temperature fluctuations at the beginning and end of each run. In order to reduce the effect of the air stream on the balance and on the model mount, the portions of the balance projecting into the measuring chamber were baffled. The forces acting on the mounting could not be completely eliminated; this necessitates measuring separately the forces acting on the mounting, which can then be subtracted from the forces acting on the mounting and model to give the forces acting on the latter. From time to time, the balance requires calibration, for which a special calibration device has been built.

2. Laval nozzles.

The Laval nozzle built into the measuring chamber must accomplish two objects.

It must regulate the speed of the entering air so that the supersonic velocity desired is established in the measuring chamber. This object is accomplished by using a Laval nozzle, in which a convergent- is joined to a divergent section. Sonic velocity is reached in the throat, and supersonic in the divergent section. In conformance with the laws of aerodynamics, the ratio of throat to exit area fixes the value of the supersonic velocity reached. The exit area of the nozzle is the area of the measuring chamber (40 x 40 cm). In order to attain different supersonic velocities in the measuring chamber, nozzles of different throat areas must therefore be used.

Furthermore, the nozzle must regulate the flow in such a way that the air stream is parallel to the axis of the tunnel and of constant velocity over the entire cross section of the measuring chamber for the entire length of the model. This object is attained by shaping the nozzle walls in accord with a graphic method of Prandtl and Busemann, which accomplishes the stepwise integration of two simultaneous partial differential equations. This means that in the case of super-sonic flow - as contrasted with sub-sonic flow - the nozzle walls must follow a definitely fixed form at every point. The making of the nozzles consequently requires exceptional care. The theory of the Prandtl and Busemann method assumes the frictionless flow of an ideal gas. Since air is not [illegible], the [illegible] had to be empirically corrected by using Schlieren methods to [illegible] gas flow through them. The extent of the changes involved increases with the Mach number.

Figs. 7 - 11 show nozzles obtained by the Prandtl-Busemann method for five different Mach numbers. In this method, the flow (which is continuous) is broken up into a series of small, discontinuous jumps, which occur when the lines in the figures are crossed. The lines represent Mach waves in which small but finite increases in velocity and in pressure occur. In the region where these Mach waves are absent, the pressure and flow conditions are constant; this is the region in which the model is to be studied.

Fig. 12 and 13 are reproductions of plastic models that show the increase in velocity and the decrease in pressure in a wind tunnel nozzle designed according to Fig. 7 for Ma = 1.57.

Fig. 14 shows one half of a similar nozzle (Ma = 3) ready to be built into the tunnel.

Fig. 15 shows half of such a nozzle (Ma = 2.4) in rough form.

3. The Displaceable Diffuser.

The changing from one velocity to another, and the variable pressure changes in the stream that accompany changes in the angular position of the model, require a conveniently variable cross-section in the diffuser (see Fig. 2).

This requirement is met by inserting flexible steel sheets, which may be bent to the desired degree by the action of an electric motor. This bending and the sudden pressure changes in the gas stream make great demands upon the strength of the steel, so that steel of high quality had to be used. By means of this arrangement, which serves as a coarse adjustment, regulation over a wide range is possible. For the fine adjustment, a special throttling plate is built into the displaceable diffuser.

4. Development and Construction of the Schlieren Apparatus.

a) General Considerations.

The optical arrangement for the observation of density fluctuations (Schlieren) in transparent media is based on the principle of Toepler's Schlieren method. The following considerations governed the choice of the various components of the optical system.

In the present supersonic tunnel, the 40 x 40 cm air stream must be meticulously parallel if precise experimental results are to be obtained. With the Schlieren method, it is possible to recognize any flow irregularity due to an inexactness in the nozzle wall. In this way, it is possible, by correcting this inexactness to "discipline" the nozzle until the flow is parallel and free from disturbances. Other methods, which are applicable in subsonic tunnels, fail here because every mechanical measuring device disturbs the supersonic flow and thus distorts the real state of affairs. Light, of course, has no such disturbing effect

Since the tunnel is 40 cm wide, it is important that the light beam be parallel and perpendicular in direction to the axis of the measuring chamber; otherwise, the irregularities in the air flow cannot be precisely located. Convergent beams cannot be used. In order to obtain the highest possible precision, the apparatus must be made extremely sensitive. Calculations gave 5 m as appropriate focal lengths for the optical system.

It is desirable to have a field of view somewhat larger than the maximum length of the model, which in the present case is about 40 cm; under these condistions, the flow pattern around the entire model can be observed at once. A 50 cm field was chosen.

b) Optics.

To generate parallel light, 2 objectives or 2 concave mirrors could be used. Objectives were dismissed because they have the following disadvantages: Chromatic aberration, and Schlieren in the glass and in the cementing layers. Two concave mirrors were accordingly selected. In spite of the spherical and astigmatic errors of those mirrors, it was possible to calculate their interaction in such a way as to obtain the best results possible with this optical method. The results of the calculations are given in the following section. The one mirror is spherical; the other, slightly deformed. The correction of these two mirrors was carried to the limited of geometrical optics. The mirror system itself was constructed by Zeiss, the work being of the highest quality. This type of opticalsystem was applied for the first time in the present project.

Fig. 16 is a schematic diagram of the optical system. An arc lamp, controlled by a watch mechanism, illuminates a slit through a condensing lens. The slit is located at the focus of the first concave mirror, the parallel light from which traverses the measuring chamber to fall upon the second concave mirror, from where it is reflected to strike the Schlieren edge. In order to avoid large angles of reflection at the concave mirrors, a plane mirror is inserted ca.50 cm behind the slit and another ca.50 cm in front of the Schlieren edge; these plane mirrors can be brought very close to the parallel light beam. The light finally enters the objective of a special camera, on the ground glass plate of which the size of the image of the model can be adjusted. The sensitivity of which the arrangement is capable shown in Fig. 17. Note that the field (diameter 50 cm) is uniformly illuminated, and that the Schlieren produced by the heat from a hand are clearly visible.

c) Calculation of the Optical System.

Two questions had to be settled before the mirror system just described could be adopted. The first asks how sharp an image is formed in the system by an illuminated slit. The light rays from a point do not intersect in a point, but in a bundle whose smallest diameter is still finite (see Fig. 18). The width b of this bundle determines the sensitivity of the optical system. The second question is whether the Mach angle produced in a gas stream can be reproduced without distortion. The reproducibility of the Mach angle must be calculated since this angle is used to obtain the velocity distribution in the nozzles to be used in the wind tunnel.

<u>Sharpness of the Image.</u>

Spherical mirrors of 5 m focal length were at first investigated; these were to be set up 10 m apart (see Fig. 19). Their optical axes were to be parallel and displaced to such an extent that they made the smallest practicable angle δ with s, the line connecting the mid-points of the mirrors. $\delta = 2^{\circ}$ could be attained.

The image would be ideally sharp with parallel illumination of the measuring chamber if the light rays emanating from every point of the source could be reunited in a point after reflection from both mirrors. It was not known to what degree of approximation these requirements could be realized. Calculation gave a minimum width b of about 320μ for the image of a point with parallel illumination. This result was unsatisfactory. It proved possible, however, to find a position for the light source (considered as a point) such that the divergence from the line of centers s did not exceed 8 minutes of arc for any light ray between the two mirrors. Thus the value of b could be reduced to 84μ . It was then investigated whether b could be decreased further by the introduction of parabolic mirrors p/2 = 5 m. Here also the use of precisely parallel light between the mirrors proved to be unfavorable.

For the special position (mentioned above) of the light source, the following results were obtained:

Light source - Spherical Mirror - Parabolic Mirror - Image
b = 57μ

Light source - Parabolic Mirror - Spherical Mirror - Image
b = 41μ

Light source - Parabolic Mirror - Parabolic Mirror - Image
b = 28μ

The last case also gave the most favorable light distribution. When the Schlieren edge is brought into the narrowest section of the light beam, a uniform darkening of the field is to be expected. This expectation was realized practically (see Fig. 17). With spherical mirrors, on the other hand, half-moon shaped zones of varying intensity were formed when the Schlieren edge was introduced. To summarize: the calculations showed that b could be reduced from 320 to 28μ by choosing a suitable optical arrangement and this means a corresponding increase in the sensitivity of the apparatus.

The question remained open whether even better results could not be obtained with a different position of the light source. Zeiss, who had initially advised against the use of two concave mirrors and recommended only one instead, have carried out calculations on a two-mirror system on the basis of the foregoing results.

Two mirrors were finally produced, one of which was spherical, the other being deformed beyond the parabolic shape. This plan [illegible] value b = [illegible] μ, and this value could actually [illegible] resolution. The use of the hyperbolic-spherical [illegible] combination was also preferable to the parabolic-parabolic pair because the former could be more speedily manufactured. The value b = 12 μ corresponds roughly to the size of the diffraction disk for the focal ratio (1 : 10) of the mirrors; this fact shows that the optical system selected actually reaches the limits of geometrical optics.

The Distortion of the Mach Angle.

Since half the solid angle ($\omega = 1^\circ\ 25'\ 57''$) subtended at the center of the sphere by the spherical mirror is very small, and since only light rays near the axis are in question, it seemed justifiable to base the calculation on the simple relationship $1/b + 1/g = 1/f$. Parallel illumination of the measuring chamber was assumed.

The Mach angle μ is half the interior angle of a cone. The relation of this angle to the image μ' formed by the spherical mirror is simple only when one assumes the axis of this cone to be in the horizontal plane through the center of the measuring chamber. The results are not appreciably changed if this axis is placed in any other parallel plane inside the measuring chamber; other positions of the axis do not occur in practice.

Assume a coordinate system (Fig. 20) with its origin in the center of the surface of the mirror and its x-axis coinciding with the optical axis. One then has

$$\cos\mu' = \frac{(2a-r)^2\cos^2\delta + r^2\sin^2\delta - tg^2\frac{\mu}{2}\left[(2a-r) - 2y_s\, tg\,\delta\right]^2}{(2a-r)^2\cos^2\delta + r^2\sin^2\delta + tg^2\frac{\mu}{2}\left[(2a-r) - 2y_s\, tg\,\delta\right]^2}$$

(r is the radius of the spherical mirror; x_s and y_s are the coordinates of P, the vertex of the schock wave; the relation $x_s + y_s\ tg\,\delta = a$ is valid.)

For every value of the distance a, there is according to Equation 1, an ordinate Y_s^* corresponding to a position of the Mach wave for which the Mach angle will be truly reproduced.

If a, the distance from the center of the mirror to the point where the axis of the Mach cone intersects the optical axis, is approximately equal to the focal length f of the mirror, then y_s^* approximately equals - r/2 (= - 500 cm). This leads to the conclusion that a true image of the Mach angle cannot be formed by one concave mirror alone.

But this difficulty is almost entirely eliminated by the objective of the camera. If the objective is placed at the distance f = r/2 from the center S', then the data of the following table apply for a Mach angle of 90°:

Lens radius ϱ	$\Delta\mu = \mu - \mu'$ A	B	C
r	2'6''	2'6''	2'6''
r/2	3'31''	0'31''	-2'29''
r/10	5'26''	<0'2''	-5'23''

A and C are the two points of intersection between the axis of the Mach cone and the boundaries of the field of view, B is the point lying midway between them in the measuring chamber. The equality a = f is assumed.

The table shows the distortion to be negligible. It is true that the image of the Mach angle is formed in a plane making an angle of at most 2° with the plane of the lens. The ground glass plate of the camera must be displaced relative to the lens by this angle if one wishes to avoid the slight error to which this angle gives rise.

d) Construction of the Optical System.

The following considerations governed the construction of the optical system.

The entire apparatus must be easy to move up and down, and along the measuring chamber so that every point in the chamber can be centered in the field of view. This problem was solved by mounting the apparatus on a carriage that is moved parallel to the chamber along rails by an electric motor; a second motor raises the optical system vertically on the carriage. Both displacements are controlled from the observation stand at the camera.

The optical system has to serve two wind tunnels in the same room. It is therefore mounted so that it may be simply picket up complete with carriage by a crane for transfer from one tunnel to the other. Realignment of the optical system is not necessary either after displacing it along the rails or raising it with the crane.

The light path must be completely baffled against disturbances by air currents outside the tunnel, such disturbances could be extremely serious. The optical system was planned so that even the two mirrors are completely covered; only the light source and camera are accessible.

With the relatively long light path of 20 m, the apparatus is particularly sensitive to shock. It must therefore be protected so far as possible against shock and against the excitation of resonant frequencies. Floor and wind tunnel were accordingly shock-proofed with particular care.

5. Electric Power Supply.

Electrical measurements play a large part in wind tunnel operation; e.g., the three-component balance, the electromagnetic pressure gauges, the high voltage spark for the Schlieren photographs, the oscillographic recording of rapidly changing processes. In order to have available the various kinds of electric power required, a power station was specially designed for wind tunnel operation. It includes batteries and suitable converters, and a control board by means of which the various kinds of power can be tranferred to the various laboratories. In order to avoid the laying of temporary lines, electrical conductors in easily accessible ducts connect the individual rooms. Worthy of particular mention is the converter delivered by the Aerodynamic Institute, Göttingen, for three-phase current in frequencies from 80 to 500 Hertz. With this power source, it is possible to operate small high-speed motors, which are to be used for experiments with rotating (up to 30,000 r-p-m-) models of projectiles. The usual current and voltages are also available.

Investigations of Fin Grenades ("Flügelminen") and Projectiles in the Supersonic Region.

I. Fin-stabilized Projectiles at Supersonic Velocities.

1. Spin Stabilization and Fin Stabilization ("Drallstabilisierung")

The stabilization of the projectile is the fundamental problem of external ballistics. Only a stable projectile, whose axis of least resistance coincides - at least approximately - with its trajectory can develop extreme ranges, and follow a predictable trajectory, the latter being a necessary prerequisite for hitting the target. Simply expressed, a projectile is stable when it always flies "nose forward". It is unstable when the angle between the axis and the trajectory tends to increase; this usually leads to uncontrolled motions and to tumbling. The way in which stabilization is achieved differs markedly depending upon whether the projectile is spin or fin stabilized.

Fig. 21 shows a fin grenade whose axis A has been displaced as the result of a perturbation until it makes the angle α with x, the tangent to the trajectory; because the air acts diagonally, a resultant aerodynamic force R is produced. Depending upon whether the vector R intersects the axis of the projectile in front of or behind the center of gravity S, there is instability or stability. This point of intersection will be called the center of pressure ("Luftangriffspunkt") L. In the case of the fin grenade of Fig. 21, L lies behind S owing to the action of the fins. The resulting moment of the aerodynamic forces rotates the gre-
~~nade of Fig. 21, L lies behind S owing to the action of the fins. The resulting moment of the aerodynamic forces rotates the gre-~~
nade counter-clockwise about S so that the axis of the projectile again approaches the tangent to the trajectory. The perturbation is compensated by the aerodynamic force on the projectile; we say that the projectile is "fin-stabilized". Not every projectile equipped with fins is fin-stabilized; the attaining of such stability depends upon the arrangement, form and size of the fins, and upon similar properties of the projectile proper, which must guide the (undisturbed) air flow so that the fins can "take hold"

Fig. 21 also shows instability for the case of a projectile without fins and without spin. Because there are no fins, L is in front of S and in the nose of the projectile. The resulting moment about S causes a clockwise rotation that tends to increase α

In this way, the axis of the projectile may be placed across the tangent to the trajectory.

The position of the center of pressure depends of the shape of the projectile and upon the characteristics of the fin assembly. Furthermore, it may move forward or backward with the angle of attack; its position also depends on the velocity. Sometimes one observes an appreciable movement forward of the center of pressure in fin-stabilized projectiles as they move from the subsonic into the supersonic region. Fin grenades that are sufficiently stable in the subsonic region need not be stable if they are fired at supersonic velocities. Wind tunnel investigations have been carried out to show that fin stabilization of such projectiles in the supersonic region is possible (see Figs. 31, 32, 35, 36). The correctness of the results of these investigations was demonstrated in suitable experiments with similar bodies flying through space.

In the case of normal spin-stabilized projectiles without fins, the angular momentum of the projectile, which tends to maintain the position of the axis in space, counteracts the aerodynamic forces that tend to make the projectile unstable. In addition to the resultant R shown in Fig. 21, the spin produces another aerodynamic force, the so-called Magnus force. If the proper spin is chosen, the projectile obeys neither the aerodynamic forces making for instability, nor the spin forces tending to keep the axis oriented, but its axis tends by and large to follow the tangent to the trajectory. The interaction of aerodynamic and spin forces complicates spin stabilization. It is consequently to be expected that the results of wind tunnel investigations will be easier to apply successfully in the case of fin stabilization.

2. Wind Tunnel Results for a Fin Grenade.

a) Pictures of the Flow.

It is clear from section 1 that the position of the center of pressure must be known in relation to the center of gravity if questions involving stability are to be settled. By the use of the supersonic wind tunnel it is possible to determine the magnitude, direction and line of attack of the aerodynamic forces that arise at various velocities and angles of attack. Schlieren pictures and three component measurements on the model of a fin grenade (Fig. 22) will now be presented. The investigations were carried out at Ma = 1,4 and 1,8.

The results are preliminary, for the tunnel has only been in operation for a short time. The regularly spaced Mach waves in the Schlieren photographs originate from specially produced roughnesses in the Laval nozzles; they are photographed in order to make possible a determination of the velocity distribution.

Figs. 23, 24 and 25 are Schlieren photographs for Ma = 1,4 and the angles of attack 0°, 6° and 12°; Figs. 26, 27 and 28 are for the same angles and Ma = 1,8. One observes the strong shock wave at the tip of the projectile; at Ma = 1,4, the curvature of the wave is particularly pronounced. The resistance of the fin assembly gives rise to the shock waves that emanate from the tail of the projectile. The boundary layer, which is heated by friction, is also visible; in accord with the position of the Schlieren edge, this layer is dark on the upper side of the grenade, and white on the lower. Noticeable further is the way in which the air stream diverges from the model behind the equator of the head; this divergence occurs further rearward at Ma = 1,8 than at Ma = 1,4. One observes that, at $\alpha = 0^{\circ}$, the stream diverging at the head is recaptured before it reaches the fin assembly, which means that the fins are doing their job well. As α increases, the flow obviously becomes unsymmetrical; at $\alpha = 12^{\circ}$, the gas stream escapes completely from the projectile on the under side, while it adheres well on the upper.

b) Measurements of the Forces.

Measurements of the forces acting on the fin grenade (Fig. 22) model were likewise carried out at Ma = 1,4 and 1,8 (see Figs. 29 - 36). As Fig. 6 shows, the resultant of the aerodynamic forces acting on the model is resolved into 3 components by the 3-component balance. The force A, perpendicular to the gas stream (lift) is measured directly. The force, W, in the direction of flow (total drag) is resolved into 2 components, whose sum equals W and whose difference is proportional to M, the pitching moment.

The results are presented in dimensionless form as is usual in aerodynamics. The drag coefficient is c_w

$$c_w = \frac{W}{\frac{\varrho}{2} v^2 F}$$

the lift coefficient is: c_a

$$c_a = \frac{A}{\frac{\varrho}{2} v^2 F}$$

(ϱ = air density, v = wind tunnel (or flight) velocity, F = cross sectional area at the point of largest caliber d.)

As Figs. 29 and 33 show, c_w has an approximately quadratic dependence on α. At $\alpha = 10^\circ$, c_w is about 25 % greater than at $\alpha = 0^\circ$. The drag coefficient decreases with increasing Ma, which is in accord with previous experience in ballistics. The lift (Figs. 30 and 34) is roughly proportional to α and almost independent of Ma. One sees that there is appreciable lift even at low values of α; the lift at $\alpha = 10^\circ$, for example, is roughly equal to the drag at $\alpha = 0^\circ$.

The usual dimensionless aerodynamic coefficient, c_m, for the pitching moment

$$c_m = \frac{M}{\frac{\varrho}{2} v^2 F d}$$

will not be employed since it presupposes a reference point for the moment M. As concerns stabilization, this moment must be referred to the center of gravity of the projectile in its trajectory. But this center is usually not exactly known while the projectile is being developed. It is therefore expedient to plot the position of the center of pressure against α, as in Figs. 31 and 35. This form of presentation depends only upon aerodynamic behavior and is independent of the position of the center of gravity. The center of pressure for the fin grenade is practically constant for $\alpha > 5^\circ$ and is forward from the tail by 2,0 to 2,1 calibers at both the Ma values investigated. At $\alpha < 3^\circ$, it is desirable to obtain values by extrapolation, for the direct location of the center of pressure becomes extroardinarily difficult when the angle of attack is very small. Its position is calculated from an expression that approaches 0 : 0 as α decreases.

If the center of gravity of the fin grenade whose model (Fig. 22) is being studied lies at 3,0 calibers, then the grenade will certainly be stable for oscillations of ± 15°. If, however, the weight of steel in the head were decreased, and the weight of the fin assembly were increased, so that the center of gravity moved backward to 1,9 calibres, then the center of pressure would be ahead of the center of gravity, and the grenade would be unstable A comparison of Figs. 31 and 35 shows that the position of the center of gravity is almost independent of the velocity, Figs. 32 and 36 show graphically (magnitude, direction, center or pressure) the resultants, R, of the aerodynamic forces for various angles of attack. The length of each vector is equal to the corresponding value of the coefficient defined by:

$$c_r = \frac{R}{\frac{\varrho}{2} v^2 F} .$$

3. Aerodynamic Resonanee Frequencies and Damping.

a) Aerodynamic Resonance Frequencies.

As a consequence of fin stabilization, the projectile possesses certain aerodynamic resonance frequencies, which are excited by perturbations. If these frequencies are to be damped, there must be energy absorption. This absorption is brought about by the action of aerodynamic moments that are produced by the oscillations, whence the process is called aerodynamic damping. Fin stability, aerodynamic frequencies, and aerodynamic damping are consequently interdependent in the highest degree.

Linear Law of Moments, Damping Neglected. The experimental results of Section 2b show that, for a large range of α values, the center of pressure (and hence the moment arm p, which is the distance between the centers of pressure and of gravity) may be considered constant. The results show further that lift, and hence (at small α) also the perpendicular component N

$$N = A \cos\alpha + W \sin\alpha$$

is proportional to α, to a first approximation. In other words, the aerodynamic moment $M = N \cdot p$ is approximately proportional to α (see Fig. 37, Curve a). Under these conditions, the equations governing linear vibrations may be used.

The period T of the aerodynamic resonance frequency of a projectile (moment of inertia, Θ) is given by

$$T = 2\pi \sqrt{\frac{\Theta}{c_m' \cdot \frac{\rho}{2} v^2 F d}},$$

where $c_m' = dc_m/d\alpha$.

The period T thus depends principally upon a characteristic of the aerodynamic moment. Other things equal, the resonance frequency $n = 1/T$ is proportional to the velocity.

Linear Law of Moments, Damping Considered. Damping by the air affects the period T. The differential equation for the oscillation of a fin-stabilized projectile about its center of gravity, velocity constant, is:

$$\Theta \ddot{\alpha} + R\dot{\alpha} + a^2\alpha = 0$$

($\dot{\alpha}$ and $\ddot{\alpha}$ are the first and second derivatives of α with respect to time; a^2 is used to represent the denominator of the fraction under the radical above.)

Justification for assuming the damping moment of the air ($R\dot{\alpha}$) proportional to $\dot{\alpha}$ will be given later (Section b). On this assumption, the period is

$$T = \frac{2\pi}{\sqrt{\frac{a^2}{\Theta} - \left(\frac{R}{2\Theta}\right)^2}},$$

which shows that air damping acts to lengthen the period of the aerodynamic resonance frequency.

Cubic Law of Moments, Damping Neglected. The linear law of moments is a first approximation. If c_m as a function of α is determined more exactly, one finds that the results of wind tunnel investigations can often be better expressed by the use of a cubic law (Fig. 37, curve b), as follows:

$$\Theta \ddot{\alpha} + a^2\alpha + b^2\alpha^3 = 0$$

(a^2 and b^2 are the positive constants of the cubic parabola.)

The solutions of this equation are elliptic functions. The period T depends upon α_0:

$$T = 4K \sqrt{\frac{\Theta}{a^2 + b^2\alpha_0^2}}.$$

K is one-fourth of the real period of the elliptic cosine, cn, thus:

$$K = \int_0^{\frac{\pi}{2}} \frac{d\chi}{\sqrt{1-k^2 \sin^2\chi}}$$

with the modulus

$$k = \sqrt{\frac{\alpha_0^2}{2\left(\frac{a^2}{b^2} + \alpha_0^2\right)}}.$$

According to this equation, T decreases as the amplitude α_0 increases. If damping by the air is neglected, the experimental results (lift, drag, center of pressure) in Section 2 thus suffice for the calculation of the aerodynamic resonance frequencies.

Cubic Law of Moments, Damping Considered. Upon consideration of damping by air, the simple cubic law become

$$\theta\ddot{\alpha} + R\dot{\alpha} + a^2\alpha + b^2\alpha^3 = 0$$

No explicit solution of this equation is presently known. Consequently, approximation formulas were developed, each valid for one quarter of an oscillation, for the practical evaluation of the diagrams recording the oscillations of fin-stabilized projectiles, (see section 3d and Figs. 40 and 41). Let T_1 and T_2 be the times of duration of the first and second quarters of an oscillation; let α_0 be the displacement at the beginning of the first quarter, and α_{T_2} the displacement at the end of the second quarter; and define the "Half-decrement":

$$\Delta\left\{\tfrac{1}{2}\right\} = \left|\frac{\alpha_0}{\alpha_{T_2}}\right|$$

then

$$\Delta\left\{\tfrac{1}{2}\right\} \approx e^{\frac{R}{2\theta}(T_1+T_2)} \sqrt{\frac{a^2 + b^2\alpha_0^2 e^{-\frac{R}{\theta}(T_1+T_2)}\, e^{-\frac{R}{2\theta}T_1}}{a^2 + b^2\alpha_0^2 e^{-\frac{R}{2\theta}T_1}}}$$

When $b^2 = 0$, this equation reduces to the formula for the half-decrement of a damped harmonic vibration.

There are cases of aerodynamic stability more complicated than those corresponding to the simple curves a and b of Fig. 37. If curve b remains tangent to the α axis in the neighborhood of the origin, then the projectile behaves indifferently in this region, and the aerodynamic forces do not necessarily direct it along the tangent to the trajectory. Cases like that of Fig. 37, curve c, occur, in which there is instability near $\alpha = 0^\circ$, and the axis of the projectile find a stable position only when the displacement α_s is reached. Since the processes involved occur in space, the stable positions for the point of the projectile lie on a circle. We then speak of stability on a circle as contrasted with at a point (Fig. 37, curves a and b).

b) The Origin of Aerodynamic Damping.

The aerodynamic damping moment M_d, results from the oscillations of the projectile about its center of gravity. In the previous section, the assumption:

$$M_d = R\dot{\alpha}$$

was made, and we shall now show that this simple relation approximates the actual conditions.

The aerodynamic forces responsible for the damping moment can be visualized in the simplest case by examining an oscillating plate, the angles of attack being small (Fig. 38).

Let a rectangular surface F of width d and length L revolve with angular velocity $\dot{\alpha}$ about an axis through its center of gravity S. Then the element of surface dF moves with the velocity

$$w = l\dot{\alpha}$$

l being the distance of the element from the axis. If an air stream of velocity v is directed against the plate, the angle of attack α being small, then the rotation of the plate adds to the angle of attack an increment $\beta = w/v$. β varies with l and changes in sign as one crosses the axis. The contribution by dF to the damping moment M_d is given by

$$dM_d = c_n(\beta)\, dF \cdot \frac{\varrho}{2} v^2 l.$$

Here c_n is a coefficient giving the force perpendicular to dF for the angle of attack β. For small β, we may assume

$$c_n(\beta) = c\beta,$$

where $c = dc_n/d\beta$ at $\beta = 0$.

We now have

$$dM_d = c \cdot dF \cdot \frac{\varrho}{2} v l^2 \dot{\alpha}.$$

this is the contribution of the element of surface dF to the damping moment M_d. Integration over the entire surface (after substituting for dF) gives

$$M_d = \frac{\rho}{2} \cdot d \cdot v \cdot 2\dot{\alpha} \int_0^{L} c\, l^2\, dl$$

or

$$M_d = c_d \frac{L^3 d}{24} \cdot \rho\, v \cdot \dot{\alpha}.$$

Here c_d is a sort of average value, taken over the entire surface, of c. The dimensionless coefficient c_d will be called the coefficient of aerodynamic damping; the last equation defines c_d unequivocally in terms of M_d.

The formula developed for this simplified case may serve as an approximation for solids of rotation (caliber d and length L) with and without fin assemblies. In other words, at constant air density and at constant velocity, one may assume

$$M_d = R \cdot \dot{\alpha}$$

for projectiles of the type under discussion.

Expressed in terms of R, c_d becomes

$$c_d = \frac{24R}{L^3 d \rho v}.$$

The derivation of this formula supports the expectation that these values of c_n for projectiles with and with out fin assembly will be equal in order of magnitude to $dc_n/d\alpha$ for the projectile in question. Wind tunnel measurements have already shown that $dc_n/d\alpha$ lies near unity for wings shaped so that $L > d$. It follows therefore, that c_d should be of the order of magnitude unity also for projectiles; the experimental results support this conclusion (see Section 3d).

c) The Law of Similarity for Aerodynamic Damping.

The dimensions of R are m.kg.sec., and its value is therefore different for the model and the full-size object, even though the two are geometrically similar. If the aerodynamic damping is to be measured in a wind tunnel, and the results are to be translated to actual practise, then it is necessary to have a dimensionless coefficient, such as c_d, to make possible the translation

The value of R will depend essentially on the velocity v, the air density ρ, and the caliber d. Dimensional considerations then show that $v \cdot \rho \cdot d^4$ is the only possible combination of these quantities that could have the dimension of R. The ratio:

$$\chi = \frac{R}{v \cdot \rho \, d^4}$$

is therefore a dimensionless damping coefficient. This coefficient has the disadvantages that its value differ by several powers of 10 for bodies of different shapes; further, the coefficient cannot be visualized in aerodynamics terms. In its place, the coefficient c_d, which has the same dimensional make-up as χ, will be used. As we have seen,

$$c_d = \frac{24 R}{\rho \cdot d \cdot L^3 v}$$

can be visualized, and it does have convenient values near unity in order of magnitude. In reality, the value of the damping constant R depends not only on v, ρ, and d, but also on the viscosity μ, on the compressibility of the air (which can be expressed in terms of a, the velocity of sound) and on the frequency n of the oscillations. Similarity considerations lead to the result

$$c_d = f\,(Re,\ Ma\ N)$$

where $Re = vd\rho/\mu$, the Reynolds number

$Ma = v/a$, the Mach number

$N = nd/v$, the dimensionless frequency coefficient of the oscillations. In analogy with the behavior of c_a and c_w, it is justifiable to expect that the influence of the Mach number on c_d will predominate over that of the Reynolds number in the supersonic region. The dependance of c_d on N will have to be established experimentally.

d) The Experimental Study of Aerodynamic Resonance Frequencies and Damping in the Supersonic Wind Tunnel.

If the aerodynamic resonance frequencies and the related aerodynamic damping are to be evaluated quantitatively, wind tunnel measurements in addition to those of Section 2b are necessary. The following is a suitable method of doing this (see Fig. 39). The model is mounted in the tunnel and on ball bearings,+) so that it can be rotated about an axis through the center of gravity, the position of which must correspond to that in the full-scale projectile. The model is now clamped at an angle of attack of, say, 10°, and the air stream of the tunnel is started. When a constant flow velocity has been reached, the model is unclamped. A fin-stabilized model will then execute oscillations about its

+) Small models are now supported by the thinnest practicable steel wire (H.A.S.)

null positions ($\alpha = 0^{o}$) and the amplitude of these oscillations will gradually decrease. It is now necessary to record these damped oscillations without distorting them, so that the period T and the damping constant R can be obtained. This is accomplished by using a beam of parallel light and two photo cells.+) When $\alpha = 0$, the same fraction of each photocell is darkened. When α is positive, the first cell receives more light, and the second cell receives less; when α is negative, the situation is reversed. A differential circuit then gives positive and negative currents corresponding to the angular displacement of the model, and these currents are recorded on an oscillograph.

Fig. 40 shows the record thus obtained of the oscillations executed by the model of a fin grenade with aerodynamic damping (Ma = 1,4). Initially, α was 10^{o}. The record reveals the action of aerodynamic damping. Since one division of the time scale is 1/50 sec., it follows that the period of the resonance frequency T is 0,17 sec., on the average. After about 40 oscillations (7 sec.), the model is at rest.

Fig. 41 is a similar record obtained on the same model with an initial α of 20^{o} and Ma = 1,8. Here, on the average, T = 0,21 sec.

The records are evaluated by the use of cubic law of moments, damping considered (Section 3a). The moment of inertia of the model being $\Theta = 0{,}00175$ m.kg.sec^{2}, we obtain

$$R = 0{,}00181 \text{ (Ma = 1,4) and } R = 0{,}00158 \text{ (Ma = 1,8)}$$

The corresponding values of the dimensionless damping coefficient are:

$$c_d = 0{,}98 \text{ (Ma = 1,4) and } c_d = 1{,}06 \text{ (Ma = 1,8).}$$

Owing to the experimental difficulties involved in their determination, these values of c_d are to be considered practically identical.

II. Investigation of Projectiles in the Supersonic Region.

The experimental work previously discussed was carried out on models that were clamped so that there was no spin. One should expect that the presence of spin will influence the form of the flow (there will be a separation of the boundary later owing to

+) Now, the oscillations are photographed with a suitable camera (H.A.L.)

the action of centrifugal forces), and that the rotation will alter the aerodynamic forces. Accordingly, provision was made to rotate the model of a 15 cm. Sandr. grenade (Fig 42) so that the aerodynamic forces arising from spin could be studied. The following information was obtained on the non-rotating model. Schlieren photographs of this model are shown in Figs. 43, 44, 45 (Ma = 1,4) and Figs. 46, 47, 48 (Ma - 1,8). Because of the well-formed nose of the model, the shock wave is relatively weak. Furthermore, there is visible-especially at Ma = 1,4 - a second shock wave that originates at the offset produced by the fuze tip. As α increases, these two shock waves diverge on the upper side of the model, and coalesce on the lower. Strong perturbations originate at the rotating bands and at the base of the projectile. The boundary layer, heated by friction, is white on the upper side and black on the lower, as is to be expected from the [illegible] of the schlieren optics. It is noteworthy that, when α is small, the air stream adheres well to the curved conical surface. As a result, the low-pressure region at the base of the projectile becomes smaller, and this decrease must in turn lead to decreased drag. At the larger angles of attack (α = 12°), one observes (particularly at Ma = 1,8) that the air stream does not adhere to the cone on the upper side, while it adheres firmly on the lower.

2. Measurement of Forces.

The results of 3-component measurements are presented in Figs. 49 - 56 in dimensionless form, as it was done in the case of the fin grenade. The considerations of Section I, 2b apply here also

with projectiles, it is again true that c_w increases approximately as α (see Figs. 49 and 53). The increase in drag with increased α is appreciable. At Ma = 1,4, the drag is 50 % greater at α = 10° than at α = 0°; at Ma = 1,8, the corresponding figure exceeds 100 %; the oscillations of the projectile thus increase the drag considerably. The drag at Ma = 1,8 is less than at Ma = 1,4, which is in accord with experience obtained in the external ballistics of slim projectiles. The coefficient of lift (Figs. 50 and 54) increases somewhat more than linearly with and is almost independent of Ma. Because there is no fin assembly the center of pressure lies well forward near the nose (Figs. 51

and 55). As α increases, the center of pressure migrates toward the rear. (Here, as in the case of the fin grenade, values for $\alpha < 3^\circ$ have been obtained by extrapolation.) At Ma = 1,4, the center of pressure at large α is somewhat higher than at Ma = 1,8. Figs. 52 and 56 contain vectors showing the magnitude and direction of the aerodynamic forces, and the center of pressure, for various values of α at the two Mach numbers investigated. It is apparent that there are appreciable lateral forces at low values of α.

SUMMARY.

The supersonic wind tunnel of the war ministry was constructed to facilitate the development of spin- and fin-stabilized projectiles. The use of a supersonic tunnel for this purpose is a relatively recent undertaking; how much such work can contribute to this development is not generally realized even now. The present book describes the supersonic tunnel, the most powerful and the best equipped in Germany, and gives some experimental results.

In the first part of the book the various types of supersonic tunnels are discussed, and the principles upon which the present tunnel operates are described. The fundamental considerations governing the choice of methods of measurement and the size of equipment are given. There follows a detailed technical description of the installation and the measuring equipment.

The second part of the book contains preliminary experimental results, which were obtained in the wind tunnel and concern problems in external ballistics. Fin stabilization, aerodynamic resonance frequencies and aerodynamic damping - all problems that arise in connection with the stabilization of non-rotating projectiles at supersonic velocities - these are clarified by means of Schlieren photographs, 3-component force measurements, and oscillation records obtained on a model of a fin grenade at Ma = 1,4 and Ma = 1,8. Finally, Schlieren photographs, and the results of measurements of the aerodynamic forces on the non-rotating model of a 15 cm. Skoda grenade, are presented for the same Ma values.

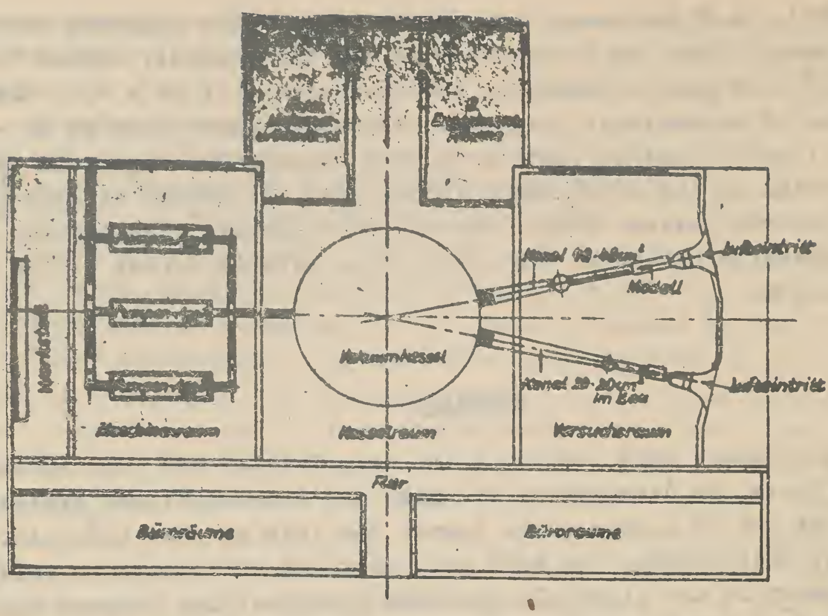
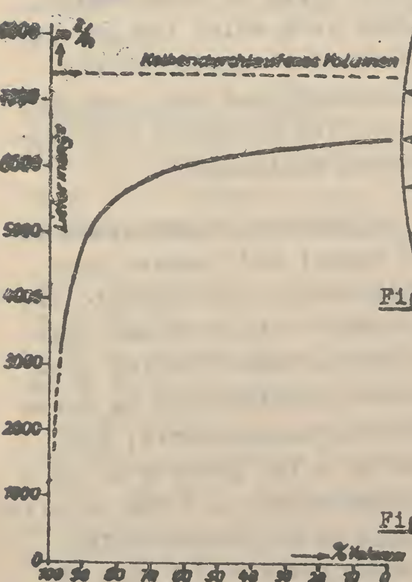


Fig. 1. Plan of the Supersonic Wind Tunnel.



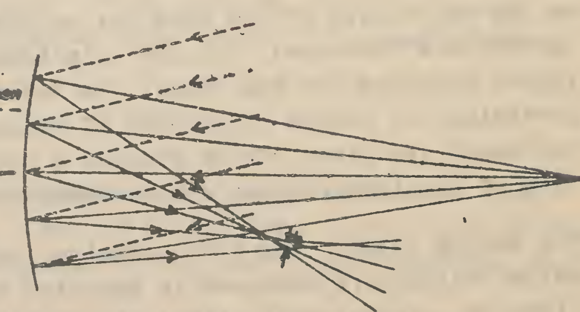


Fig. 18. Origin of the Beam width b.

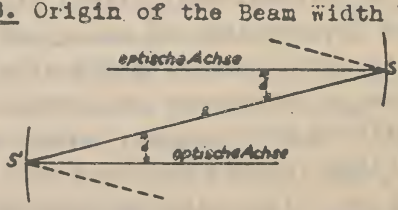


Fig. 19. Arrangement of the Concave Mirrors.

Fig. 4. Performance Curve for One of the Six Pumps.

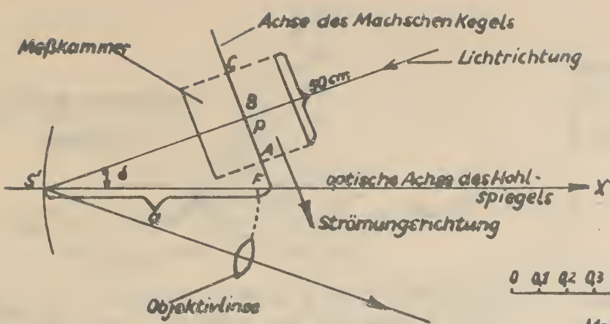


Fig. 20. Image of a Mach Angle as formed by a Concave Mirror and Camera Objective.

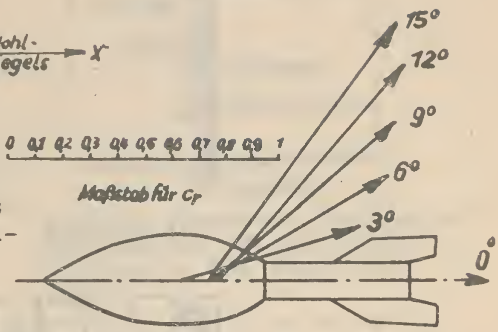


Fig.32. Vectors Showing Magnitude Direction and Center of Pressure for the Aerodynamic Forces Acting on the Fin-Grenade Model at Ma = 1,4.

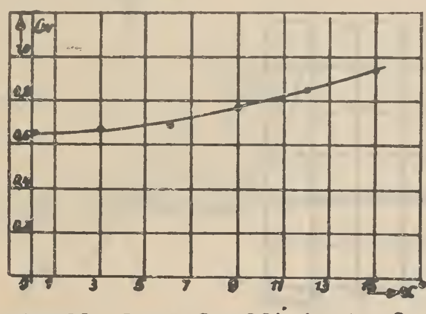


Fig.29. Drag Coefficient of the Fin-Grenade Model as a Function of α at Ma = 1,4.

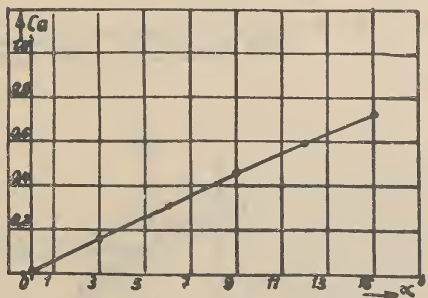


Fig.30. Lift Coefficient of the Fin-Grenade Model as a Function of α at Ma = 1,4.

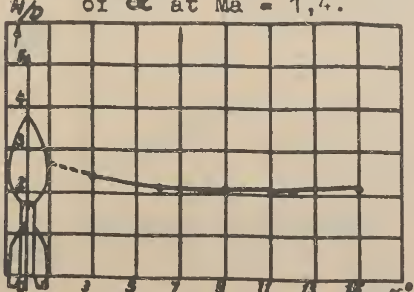


Fig.31. Center of Pressure for the Model as a Function of α at Ma=1.4.

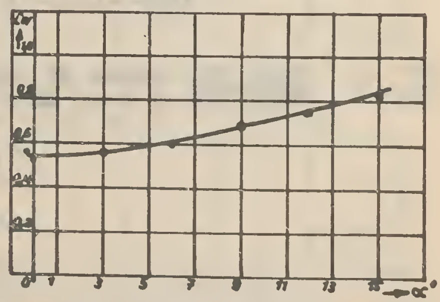


Fig.33. Drag Coefficient of the Fin-Grenade Model as a Function of α for Ma = 1,8.

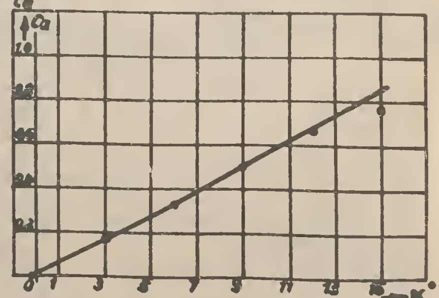


Fig.34. Lift Coefficient of the Fin-Grenade Model as a Function of α for Ma = 1,8.

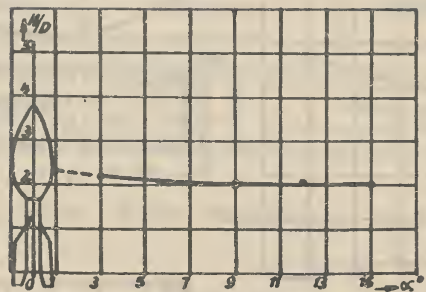


Fig. 35. Center of Pressure for the Model as a Function of α at Ma = 1,8.

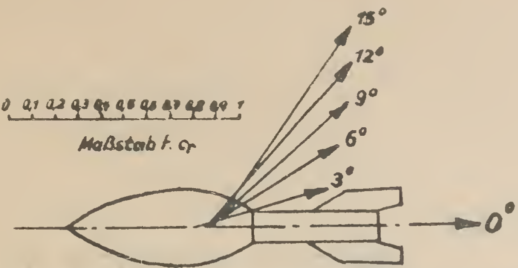


Fig.36. Vectors Showing Magnitude, Direction and Centers of Pressure for the Aerodynamic Forces Acting on the Fin-Grenade Model at Ma = 1,8.

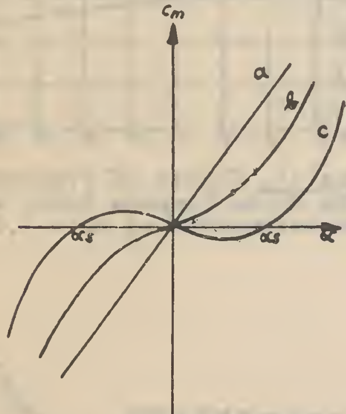


Fig.37. Aerodynamic Moment as Various Functions of α.

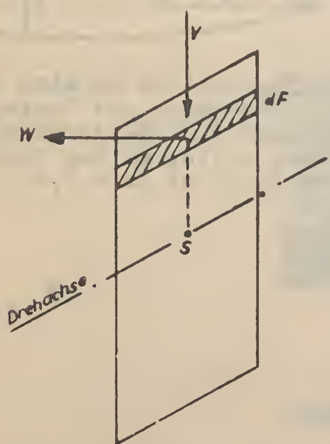


Fig.38. Origin of Aerodynamic Damping.

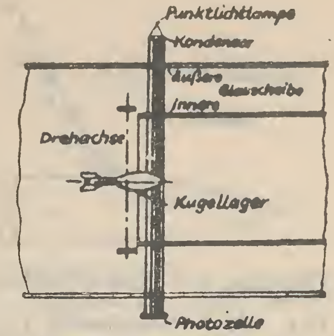


Fig.39. Apparatus for the Determination of Aerodynamic Damping in the Supersonic Tunnel.

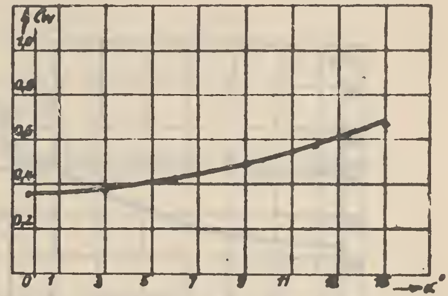


Fig.49. Drag Coefficient of the Skoda-Grenade Model as a Function of α at Ma = 1,4.

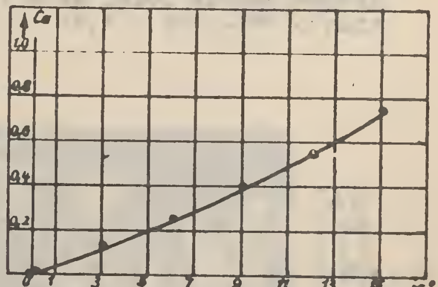


Fig.50. Lift Coefficient of the Skoda-Grenade Model as a Function of α at Ma = 1,4.

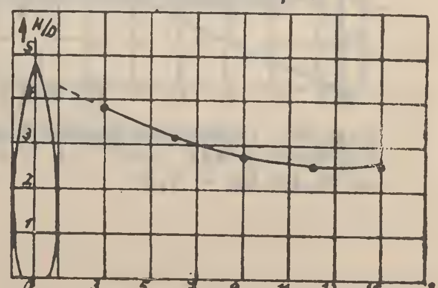


Fig.51. Center of Pressure of the Skoda-Grenade Model as a Function of α at Ma = 1,4.

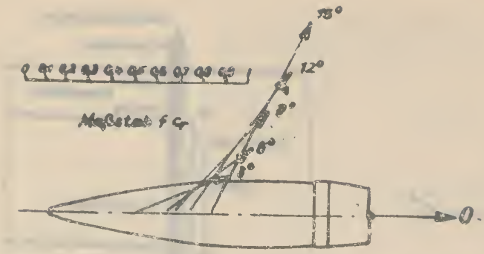


Fig.52. Vectors Showing Magnitude Direction and Centers of Pressure for the Aerodynamic Forces Acting on the Skoda-Grenade Model at Ma = 1,4.

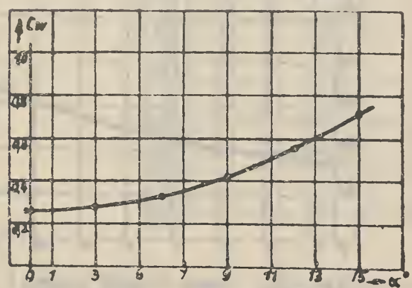


Fig.53. Drag Coefficient of the Skoda-Grenade Model as a Function of α at Ma = 1,8.

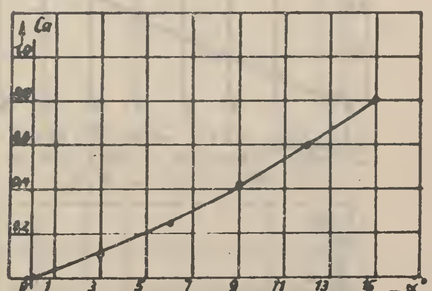


Fig.54. Lift Coefficient of the Skoda-Grenade Model as a Function of α at Ma = 1,8.

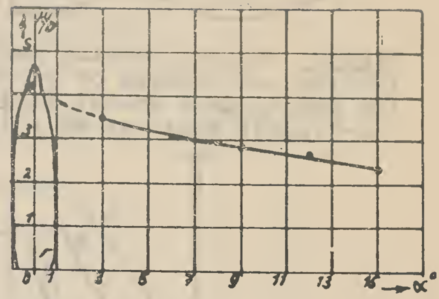


Fig.55. Center of Pressure of the Skoda-Grenade Model as a Function of α at Ma = 1,8.

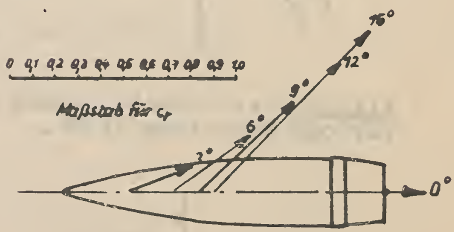


Fig.56. Vectors Showing Magnitude Direction and Centers of Pressure for the Aerodynamic Forces Acting on the Skoda-Grenade Model at Ma = 1,8.

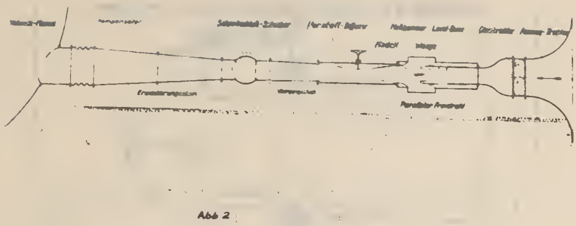


Fig. 2

Schematic Diagram of the Supersonic Wind Tunnel

Fig. 3

View of the Measuring Section.

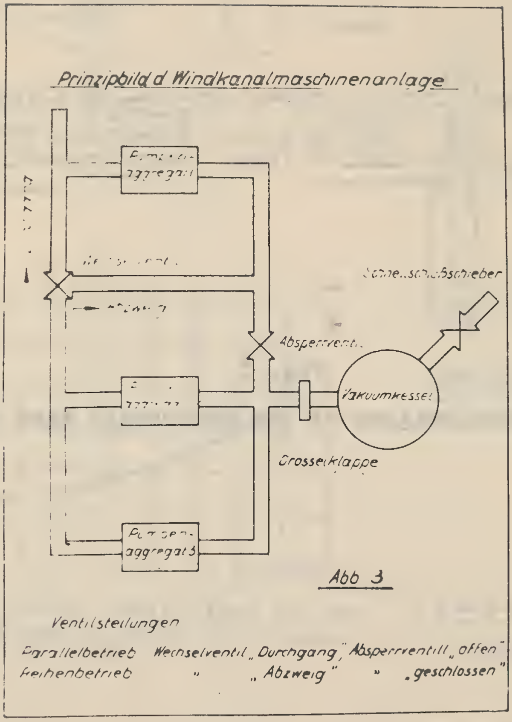
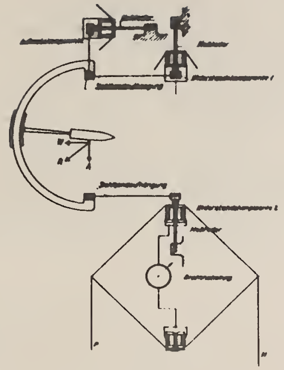


Fig. 5

Schematical Diagram of the Machine Installation



Schema der Dreikomponentenwaage
Abb. 6

Fig. 6
Schematical Digram of the 3-Component Balance

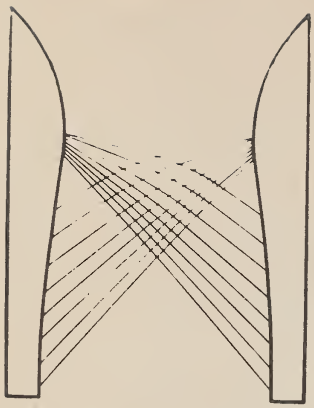


Fig. 7
Supersonic Nozzle for Ma = 1,57
(540 m/sec.)

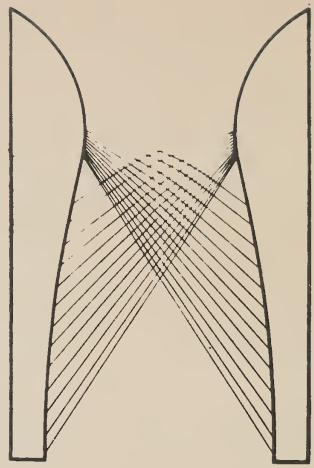


Fig. 8
Supersonic Nozzle for Ma = 1,88
(640 m/sec.)

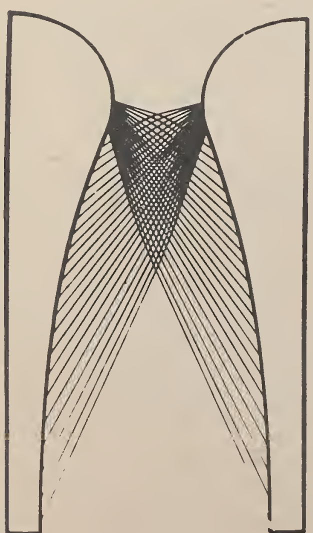


Fig. 9
Supersonic Nozzle for Ma = 2.5
(850 m/sec.)

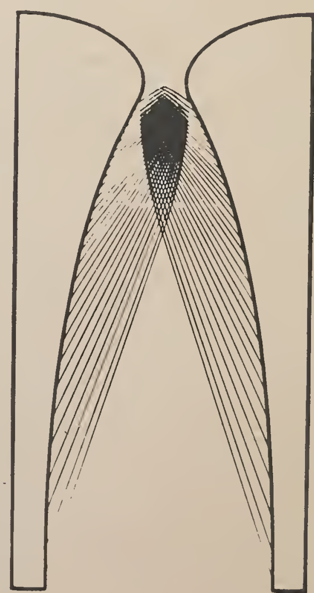


Fig. 10
Supersonic Nozzle for Ma 3,3
(1120 m/sec.)

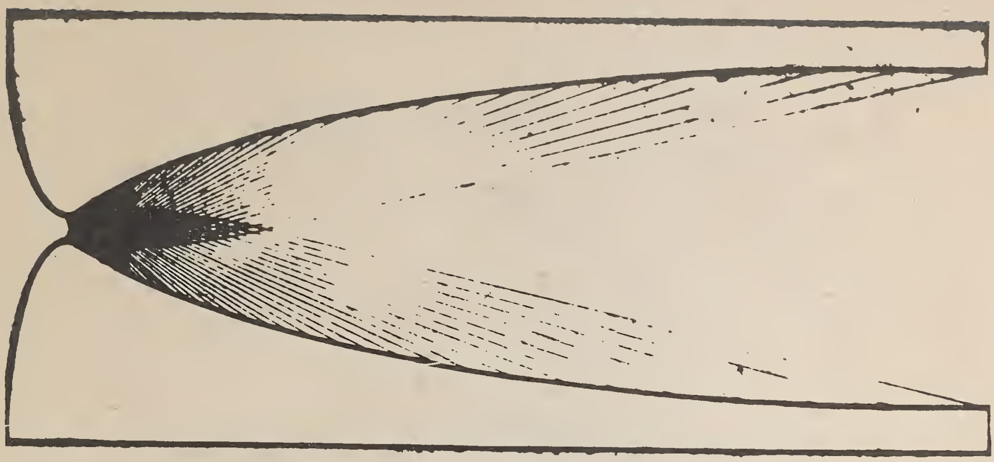


Fig. 11
Supersonic Nozzle for Ma = 4,4
(1490 m/sec.)

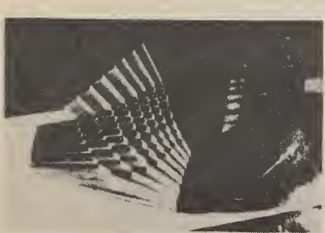


Fig. 12
Plastic Model Showing the Increase of Velocity in the Wind Tunnel Nozzle for Ma = 1,57.

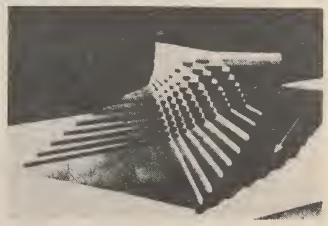


Fig. 13
Plastic Model Showing the Decrease of Pressure in the Wind Tunnel Nozzle for Ma = 1,57.

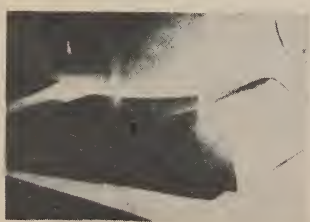


Fig. 14
Supersonic Nozzle for Ma = 3,0

Fig. 15
Supersonic Nozzle (Unfinished) for Ma = 2,4

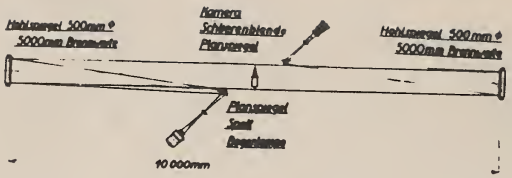


Abb 16

Fig. 16
Schematic Diagram of the Schlieren Apparatus.

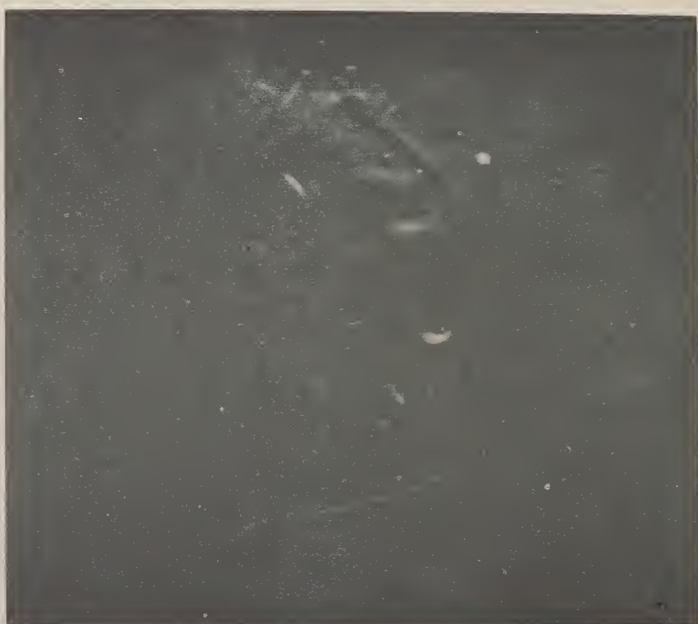


Fig. 17
Field of View (50 cm. diameter) of the Schlieren Apparatus. (Note Schlieren Caused by Heat from the Hand.)

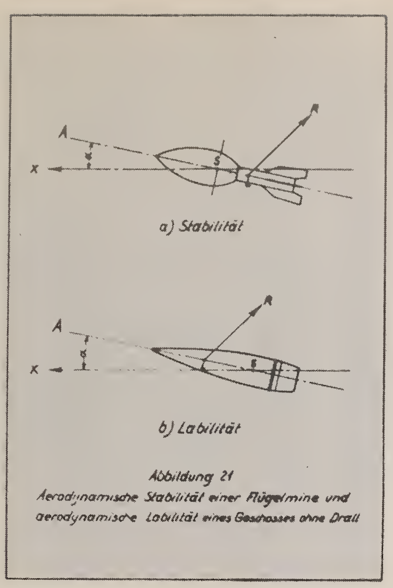


Fig. 21

Aerodynamic Stability of a Fin-Grenade (Shell)
Instability of a Non-Rotating Projectile.

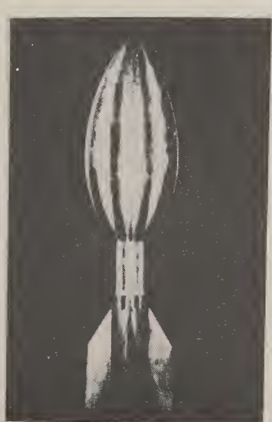


Fig. 22

Fin-Grenade (Shell) Model Studied in the Wind Tunnel (Length 29 cm. Largest Diameter, 7 cm.)

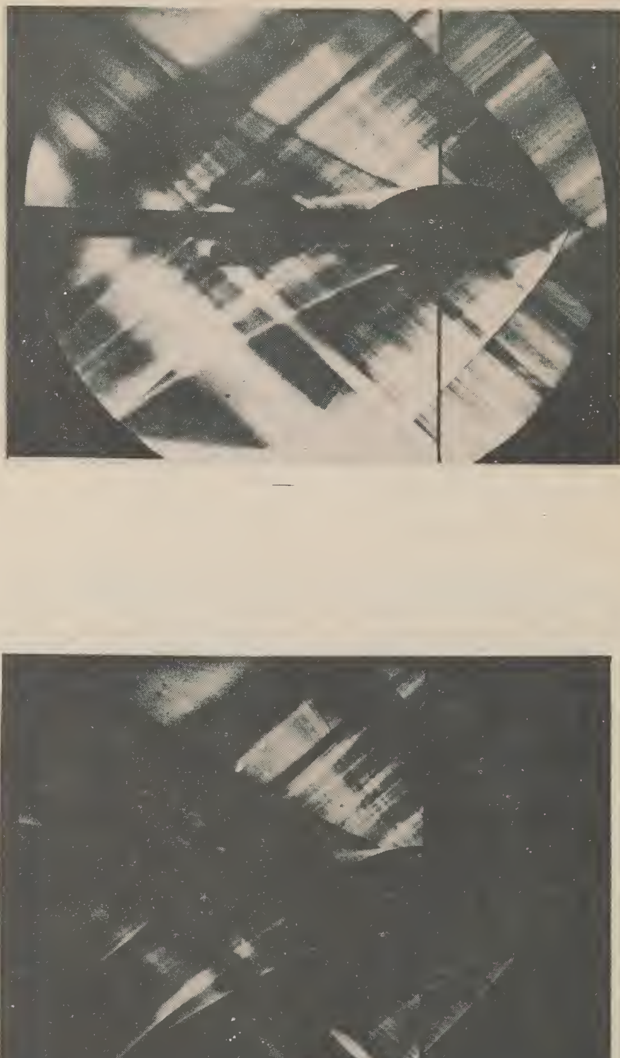


Fig. [illegible]
Schlieren Photograph [illegible]
(α = 6°, [illegible])

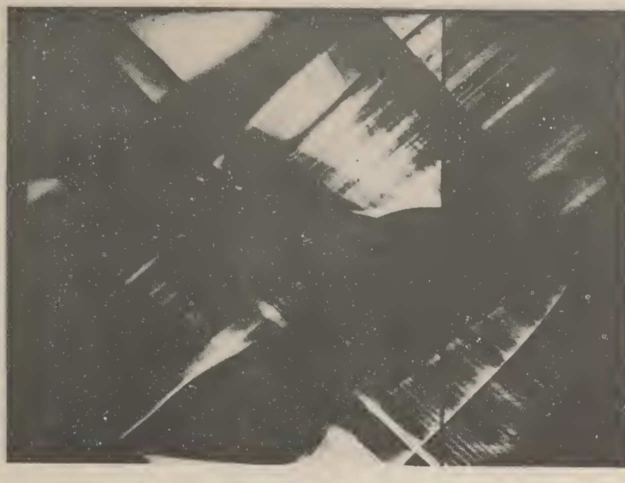


Fig. 25
Schlieren Photograph of the Fin-Grenade Model
(α = 12°; Ma = 1,4)

Fig. 26
Schlieren Photograph of the Fin-Grenade Model
(α = 0°; Ma = 1.8)

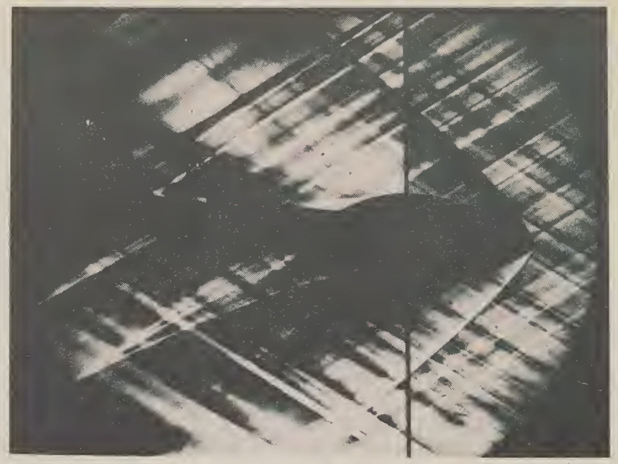


Fig. 27
Schlieren Photograph of the Fin-Grenade Model
($\alpha = 6^{0}$; Ma = 1,8)

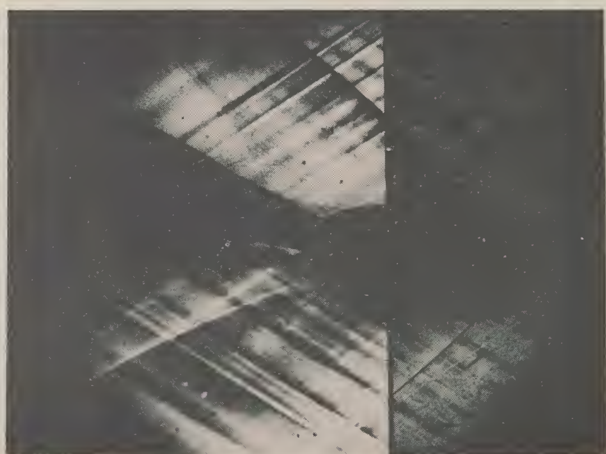


Fig. 28
Schlieren Photograph of the Fin-Grenade Model
($\alpha = 12^{0}$; Ma = 1,8)

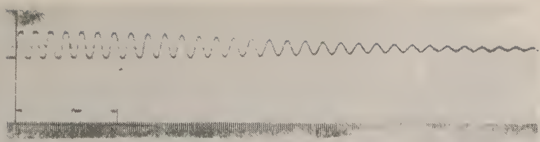


Fig. 40
Oscillation Diagram for the Fin-Grenad
Initially, $\alpha = 10^{o}$).

Fig. 41
Oscillation Diagram for the Fin-Grenad
Initially, $\alpha = 20^{o}$).

Fig. 42
15-cm. Skoda Grenade (Shell) Model (La
studied in the Wind Tunnel.

Fig. 43

Schlieren Photograph of [illegible]

at $\alpha = 0^{\circ}$ [illegible]

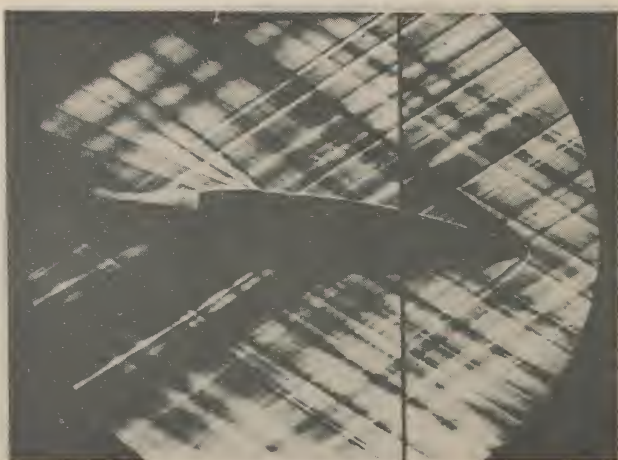


Fig. 44

Schlieren Photograph of the Skoda Model

at $\alpha = 6^{\circ}$ and Ma = 7.4

Note: The photographs for Figs 44 and 47 have been interchanged. [illegible]

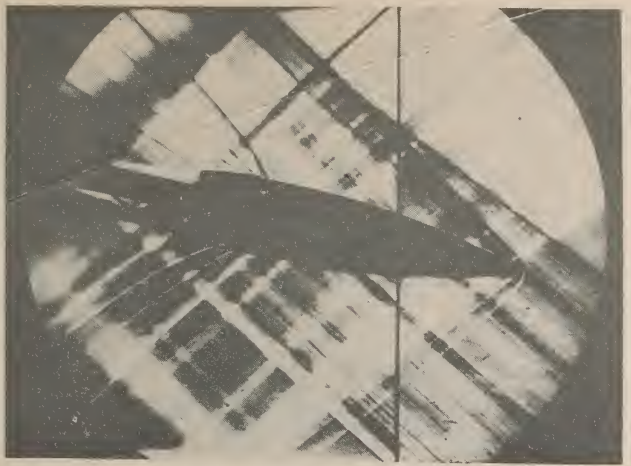


Fig. 45
Schlieren Photograph of the Škoda Model
at $\alpha = 12^{\circ}$ and Ma = 1.4

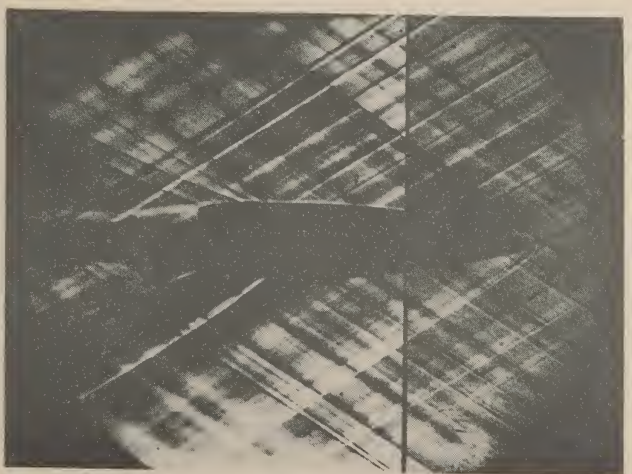
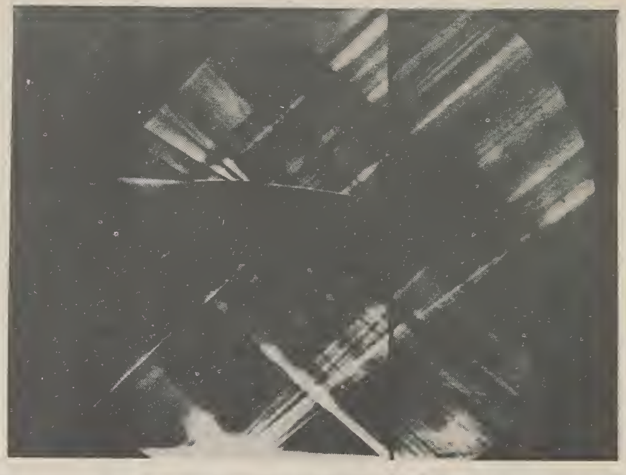


Fig. 46
Schlieren Photograph of the Škoda Model
at $\alpha = 0^{\circ}$ and Ma = 1.8



Note: The photographs for Figs. 44 and 47 have been interchanged.

Fig. 47

Schlieren Photograph of the Skoda Model at $\alpha = 6^{\circ}$ and Ma = 1.8

Fig. 48

Schlieren Photograph of the Skoda Model at $\alpha = 12^{\circ}$ and Ma = 1.8

Fig. 57

Mounting of the Model in the Wind Tunnel.

stabilizing fins

mit 6 /\ Leitwerksflossen

with 6/\ Stabilizing fins

mit 8 /\ Leitwerksflossen

with 8 /\ stabilizing fins

mit verkürztem Heck und
8 /\ Leitwerksflossen

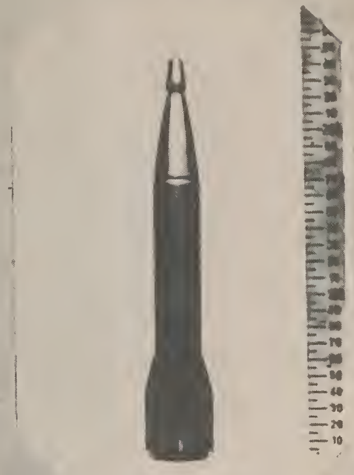
with shortened rear and
8 /\ Stabilizing fins

Development of the 10.5/7.5 cm WHL-Shell for Paw 1000

Entwicklungsformen der 10.5/7.5 cm WHL-Granate für Paw 1000.

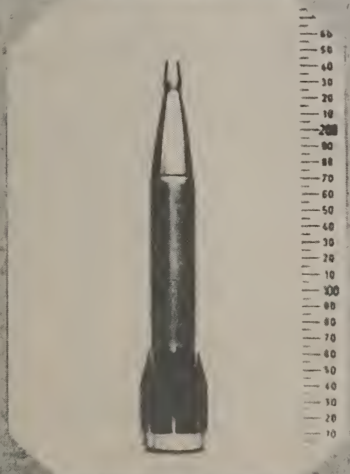
mit verkürstem Heck und Zwischenstück und 8 /\ Leitwerksflossen.

with shortened rear and intermediare band and 8 /\ stabilizing fins.



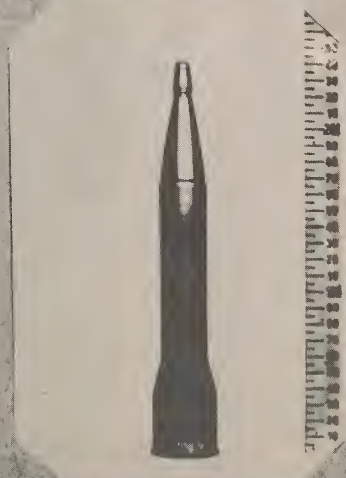
mit Heckscheibe und 8 ‖ Leitwerksflossen

with rear disc and 8 ‖ stabilizing fins



mit Zylinderring und 8 ‖ Leitwerksflossen

with Zylinderring and 8 ‖ stabilizing fins



Heck mit konischem Ring und 8 ‖ Leitwerksflossen.

Rear with conical ring and 8 ‖ stabilizing fins

Development of the 10.5/7.5 cm. WHL shell for PAW 1000

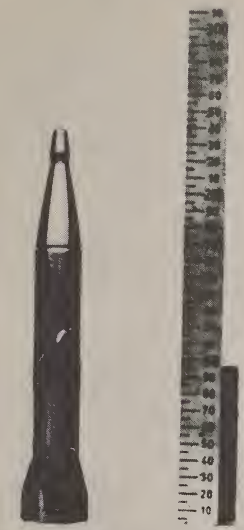
With 8 || stabilizing fins.

With 8 /\ stabilizing fins.

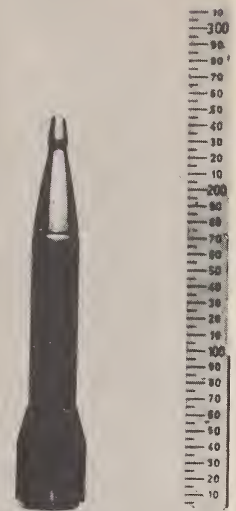
With 8 /\ stabilizing fins.

With shortened rear and
8 /\ stabilizing fins.

Development of the 10.5/7.5 cm. HL shell for Raw 1000



With shortened rear and intermediate band and 8 /\ stabilizing fins



With rear disc and 8 || stabilizing fins.

With cylinder ring and 8 || stabilizing fins

Rear with conical ring and 8 || stabilizing fins.

RESTRICTED

RESTRICTED