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TECHNICAL REPORT NO. 229-45

TRAINERS FOR OPERATORS OF GUIDED MISSILES

September 1945

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File: A9-16(3)(50/Hn)

Serial: 1227

28 September 1945.

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From: Chief, U.S. Naval Technical Mission in Europe.  
To : Chief of Naval Operations (OP-16-PT).  
Subject: U.S. Naval Technical Mission in Europe Technical  
Report No. 229-45, Trainers for Operators of Guided  
Missiles - Forwarding of.

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TECHNICAL REPORT NO. 229-45

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TRAINERS FOR OPERATORS OF GUIDED MISSILES

SUMMARY

This report presents information on the use of synthetic trainers for operators of guided missiles, including flak rockets, glide bombs, and high angle bombs. In those instances where subject trainers were evacuated, disposition of equipment has been indicated.

September 1945

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## TRAINING DEVICES FOR OPERATORS OF GUIDED MISSILES

### I. Introduction.

The development of guided missiles in Germany has been closely paralleled by the development of synthetic devices to be employed in the training of the operators of guided projectiles. Training devices have been constructed for guided flak rockets, high angle bombs (Fx 1400) and glide bombs (HS 293) and in addition, trainers for air-to-air bombing were under consideration. The design work for a guided aerial torpedo trainer had been completed and one such device had been partially constructed when hostilities ceased.

These devices cover a wide range of complexity. An example of one the simpler types is the Henschke trainer described below. An example of a complicated device is Schedling's Computer for the trajectories of rockets.

### 2. Henschke Basic Trainer for Operators of Remote Controlled missiles.

This device was designed and constructed by Dr. Ulrich Henschke, Director of the Medical Research Institute at Garmisch-Partenkirchen. The fundamental claim for this trainer is that it trains students to control objects subject to constantly increasing accelerations, as for example falling bombs.

The training period is four hours a day for four weeks, a total of 112 hours. Dr. Henschke claims that subjects trained on this device, after being given one hour of familiarization with more complicated training devices, were able to operate the new equipment as well as subjects originally trained on the other devices. No data were available to substantiate these claims.

The trainer has the following advantages:

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I. Introduction (2) (Cont'd).

1. It is small and compact, thus permitting many students to practice in a limited area.
2. It is simple to construct, inexpensive, and requires little or no maintenance.

The trainer has the following disadvantages:

1. It does not duplicate the accelerations of a falling object over a period of time.
2. The controls do not duplicate the actual controls employed with guided missiles, either as to "feel" or as to the position in which they are operated.
3. The controls are too sensitive, and permit the course of the "missile" to change much more rapidly than in the case of an actual bomb. The trainer is housed in a box approximately 18" x 18" x 12". The student sits behind the box and controls the motion of a 1" steel ball by means of a stick. The ball rests in a tray supported in a double-gimbal arrangement which permits the tray to be tilted either vertically or laterally, the motion and direction of the ball being controlled by the stick. The movement of the ball is reflected by a mirror set at a 45 degree angle in the lid of the box to a second mirror ten feet away, in which the student observes the motion of the ball. A picture of the device is in Appendix I.

Col. Otto Schaper who had charge of the development and construction of training equipment for the German Air Force has stated that this trainer is of value as an introduction to the manipulation of trainers which duplicate more precisely the actual bombing situation. Unless controlled tests demonstrate that individuals trained on this basic trainer are equally as competent as individuals trained on more complicated devices, it is recommended that the Henschke trainer be used only for basic training. In any case, training time, 112 hours, seems excessive.

A sample of this trainer has been shipped to Special Devices Division, Bureau of Aeronautics, Washington, D.C.

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1. Introduction (Cont'd).

3. Device for Demonstrating the Effects of Motion Gravity and Drift on a Falling Object.

This device was developed by Herr Hans Wiedemann at Eching b. Freising, under the supervision of Col. (Ing.) Otto Schaper of the G.A.F. In Appendices II A and B, Col. Schaper has discussed the fundamental objectives of the device, namely, the visual demonstration to the untrained and relatively uneducated personnel employed by the Germans as bombardiers of the effects of gravity, own speed, and drift on a falling object.

One of these trainers, the Grundlehrmodell fur Bombenwurf basic device for training bombardiers has been shipped to Special Devices Division, Bureau of Aeronautics, Washington, D.C.

4. Trainer for Operators of High Angle Guided Bombs (Fx 1400).

(Truppenubungsgerat fur ferngelenkte Fallbomben).

This trainer (See Appendix II C) can be used either for training personnel in dropping high level non-guided missiles, or in the use of guided bombs. It consists of the following basic elements:

- (1) Power supply and transformer.
- (2) A "target" whose motion simulates the apparent motion of an actual target.
- (3) A Loft 7 Bombsight
- (4) The controlling mechanism.

The device has the following advantages:

(1) It is extremely compact. The overall dimensions are approximately 4' x 6' x 4', and weight including the power supply, when ready for shipment is approximately 750 pounds.

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I. Introduction (Cont'd).

(2) All equipment, such as the bombsight and the steering mechanism, are standard operational equipment.

(3) Great care has been taken to simulate the position of controls and control forces and to reproduce from intervals correctly.

(4) The instructor can set up a problem for the student, and can determine and demonstrate just when and why the error occurred in the bombing run.

One complete device including the power unit has been shipped to Special Devices Division, Bureau of Aeronautics, Washington, D.C.

5. Trainer for Operator of Guided Glide Bombs (HS 293) and High Angle Bombs.

This device was constructed by Herr H. Wiedemann under the direction of Col. Schaper. The entire mechanism is housed in a cabinet approximately 18" x 24" x 48". It consists essentially of a control mechanism for the bombardier, a projection machine which moves a ship across a screen at a constant speed, and a calculating mechanism which controls the time of flight, the speed and the trajectory of the "bomb". (For details see Appendix II D).

The device has the following advantages:

- (1) It can be easily shipped by air, as it weighs 150 pounds.
- (2) It duplicates the "fuel" of the actual instruments.
- (3) It duplicates the problems of time and acceleration with a real bomb.
- (4) It has great appeal to the student.

One sample has been shipped to Special Device Division, Bureau of Aeronautics, Washington, D.C.

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I. Introduction (Cont'd).

6. Trainer for operators of Guided Flak Rockets.

This trainer was devised by Dr. Johann Schedling, of Bad Reichenhall, Krichberg 1, for the purpose of studying the flight paths of guided rockets. The device gave only qualitative results, so it was decided to prepare a more precise mechanism which would give both qualitative and quantitative results, and to employ the original device for training purposes.

The original trainer has been partially destroyed and, at present, is dismantled. It is estimated that it would take four weeks to place it in working order, and prepare it for shipment. In view of the difficulties in securing personnel and payment for private labor, it did not appear advisable to attempt to complete this trainer.

The second device had not been completed at the cessation of hostilities. It is estimated that it could be completed in 4 to 6 months by a crew of twenty competent men. This device would be of the greatest value for studying the following types of problems.

- (1) The minimum height of the target, when a flak rocket attack would be profitable.
- (2) The relative efficiency of guided flak rockets (GFR) against approaching and receding aircraft.
- (3) The aerodynamic shapes necessary for stability and maneuverability of GRF (Guided Flak Rockets).
- (4) The efficiency of gyros in various positions of the rocket.
- (5) The trajectory of various types of rockets, fired under a wide variety of conditions.
- (6) The efficiency of various controlling mechanisms.
- (7) Certain psychological factors encountered by the operators of GFR.

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I, Introduction (6) (Cont'd).

(8) Whether one or two operators are needed for fire control;  
i.e., one for azimuth and one for zenith.

Prepared by:

JACK W. DUNLAP,  
Comdr, U.S.N.R.

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APPENDIX I

SELECTION AND TRAINING IN THE PROCESS  
OF REMOTE CONTROL

Treater: Henschke.

One of the most difficult tasks in new arms is to handle remote controlled guns, bombs and rockets. Therefore, selection and training of operators of remote controlled arms need great care especially, because it is possible to select good men out of a great number.

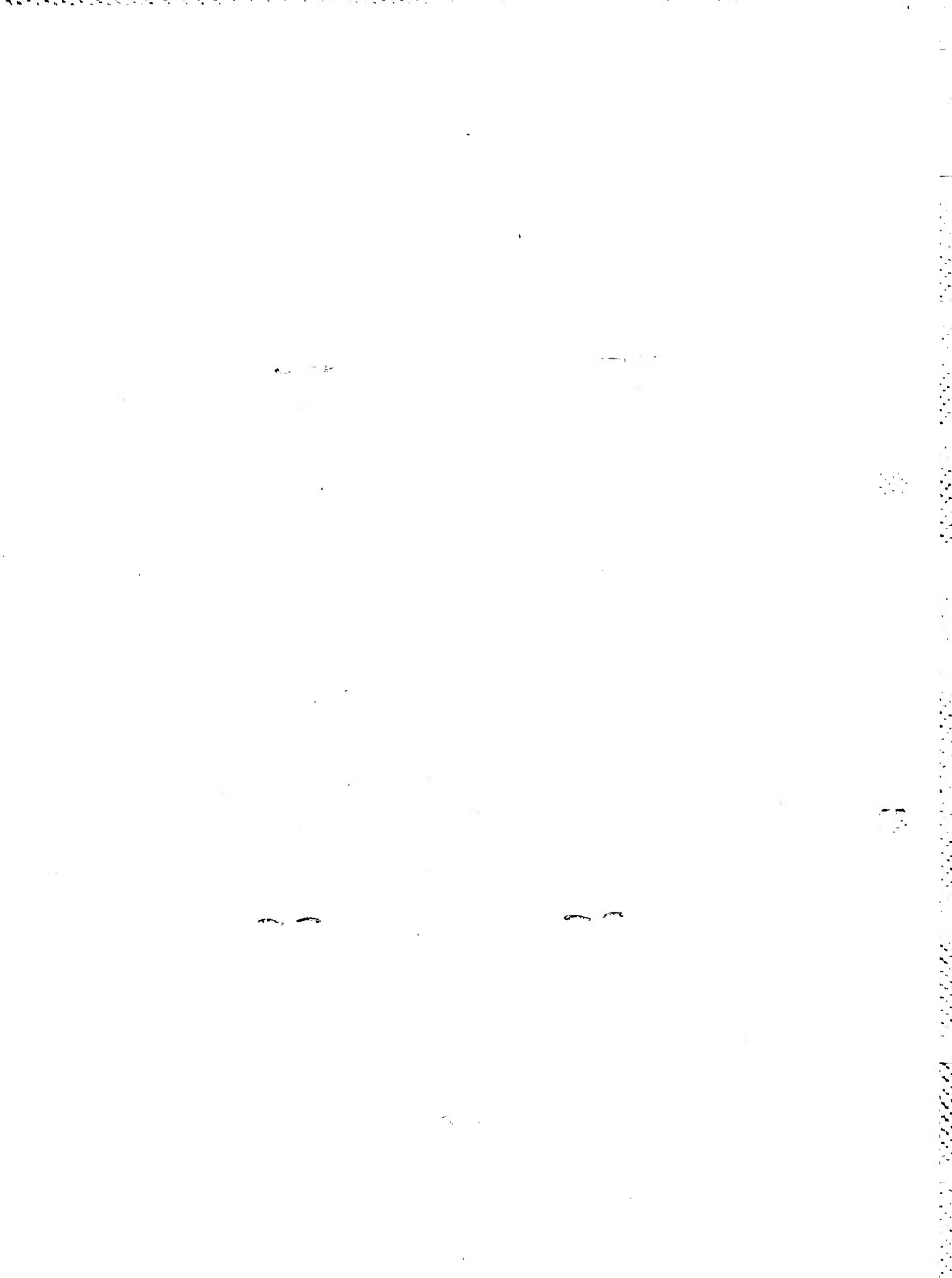
Investigations were conducted not only in these special functions. Also the rules and foundations of selection and training were exploited. It was tried, to get general directions for selection and training with several methods.

For the construction of trainers, also were cleared up the chief physiological points of view, which must be cared of by the technician, to build effective instruments.

All the first operators for remote controlled bombs were selected and trained by us. Rules were given for selection and training and a very simple trainer was developed.

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APPENDIX II A

A BASIC TRAINING DEVICE FOR THROWING OF BOMBS

Col. Ing. Otto Schaper

1. Purpose.

The device is to demonstrate the dropping of bombs, so as to familiarize the pupil with the natural laws and the necessary observations, which are prerequisites for guided bombs and for good results in terms of hits. As the bomb aiming mechanism automatically translates all set values into the proper time of dropping by means of a built-in calculator and then automatically trips the bomb, it is not necessary to go through the quantitative and calculated examples in the lessons. The device serves to demonstrate all functions in reality, and to make the pupil understand them. Moreover, the bombardier must find out which observations are strictly important to obtain good results.

2. Handling.

The handling of the moving parts of the device by the teacher is done by pressing buttons and is fool proof. The following example best illustrates how a pupil is instructed, first in simple dropping on a stationary target, then on a moving one, and finally in taking drift into consideration.

Example: If you let an object drop in a moving train, the windows of which have been closed to avoid influences of wind, then it will hit the floor at a point exactly below the point of release. Everyone has the opportunity of observing this natural law. From this we gather that an object retains its forward motion, if it is permitted to fall freely, otherwise the point of contact with the floor would not be perpendicularly below the point of release. In this case it does not matter whether the object is an apple or a paper ball of lighter specific weight. If now you drop an object from the window of a moving train it will no longer move perpendicularly to the car, but it will stay behind that line. Moreover, paper will stay further behind than a stone (from which the differences of dropping different

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Appendix II A (Cont'd).

types of bombs can be seen.) This drag is the effect of air resistance against the forward motion. Since in an airplane, air resistance can only come from the front, when flying conditions of the dropping bomb are normal (i.e., without "slip"), the bomb will always stay behind in a plane of flight perpendicular to the earth and in the direction of the airplane axis. Even the wind does not modify this, because the wind moves plane and bomb with the same speed in relation to the earth.

(a) Bombing Stationary Targets.

First, a few bombings are shown which are released either too early or too late. Where is the proper point of release? After the teacher starts out from a correct "hit" he then puts the training device into reverse back to the point where the bomb is attached to the airplane. This is, no doubt, the point of release as the procedure can be repeated, in advance direction from here and it must again lead to a hit, which observer can easily understand.

The device shows that the hit can only happen at that instant when the "bomb trajectory beam" meets the target. The observations for bombing must therefore always start out from the bomb trajectory beam (not from the perpendicular through the airplane which indicates course). The bomb trajectory beam and its angle to the airplane, the trail angle, are known for all types of bombs. The time of falling of a bomb is also known for each altitude, and the speed of flight can be measured through observation. On the training device, the clock moves around four times from release of the bomb to the hit on the ground; this, for example, corresponds to a bomb dropping time of four seconds. If the target, as seen from the bombardier moves 10 degrees in one second then the bomb must be released when the target is  $4 \times 10$  or 40 degrees ahead of the bomb trajectory beam (not ahead of the perpendicular through the plane).

(b) Bombing of a Moving Target.

A hit on a moving target can only be made, if the target maintains its speed and course unchanged from the time of release of the bomb to the moment of impact. Since the airplanes can only to a negligible

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Appendix II A (b) (Cont'd).

extent alter its own speed while in horizontal flight, there only remains the possibility of changing course of aim. The course must be chosen in such a way that the bomb trajectory beam (this is always the trajectory of the bomb) crosses the course of the target at the very instant when the latter is a point of crossing. Therefore, maximum accuracy in choosing course and maintaining course during aiming until release of the bomb are prerequisites for the certain hitting of moving targets. The bomb must be released in such a way, that it hits the ground in the same instant as the bomb trajectory crosses the path of the target.

The training device now shows in reverse, the motion of the airplane and target, again showing that for a "hit", proportional triangles are formed by the flight path and the path of the target. Therefore the direction to the target as seen from the plane, remains unchanged during the observation. The course must therefore be chosen in such a way that the target will move exactly along the hair of the sight; at the same time the hair must be laid through the bomb trajectory beam. If the target is observed to gradually wander away, then the course must be changed to the side to which the target wanders. The crosshairs are then again to be adjusted on the target and to be watched to see whether the target now runs along the hair.

The time of release, when bombing a moving target, is ascertained as in bombing a stationary target; the lead is calculated from approach speed, multiplied by time of fall:

(c) Bombing Under Drift Conditions.

The training device demonstrates in a simple fashion, that the drift of an airplane caused by wind has the same effect upon bombing, as if the target were moving. The best way to illustrate these observations is to insert a map or an aerial photograph. It can then easily be seen, that the bomb will hit to the side of the airplane's course (red line). Here, too, the bomb will always lag behind but exactly in the axis of the airplane. But since the airplane makes a sliding motion across the map, due to wind drift, the lower point of the bomb trajectory beam will move parallel to the airplane's course across the landscape.

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Appendix II A (Cont'd)

(d) Curve of Fall.

The illustration shows the curve of a falling bomb and its origin in the bomb trajectory. The bombardier never gets to see it, as it has just been shown, for him the bomb will always disappear to the rear in a straight line. The curve of fall shows, however, why lead angle increases at smaller altitudes. The predicting interval grows smaller. From this springs the difficulty of bombing from low altitudes, because exact measurements are not possible with flat angles of observations.

APPENDIX II B

INSTRUCTIONS FOR ASSEMBLY AND OPERATION OF THE BASIC TRAINING DEVICE  
FOR BOMBING 6/2 Fl. Ub. 94-922.

ASSEMBLY INSTRUCTIONS

The apparatus is packed in its case, ready to operate. When unpacking, note the following:

1. The screws of the large side wall Nr 1, marked "heir Offnen" (open here) are to be unscrewed and the wall taken off.
2. Then unscrew cover and take it off.
3. Remove screws of base plate so that the apparatus is completely free.
4. Remove bracings of walls Nrs 2, 3, and 4 inside the case, so that the rods of the apparatus are free.
5. Then take off side walls and the apparatus is ready for use. Consult the attached instructions for use.
6. If the apparatus is to remain at destination, return the case. For this purpose the walls are not reassembled, but are returned separately on bill of lading.

Firma Henkel & Grosse, K.G.,  
Pforzheim,  
Sinumler, Str. 18.

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Appendix II B (Cont'd).

A. Connection.

Connection is made by means of the outside socket. Connect only to 24-27 volt DC lines.

B. Switching.

All switching is by means of the switch-board on front side of apparatus, which is designed to fold in. To prepare for operation, the switchboard must be folded up and the intermediate switch button "Einschalten" (on) must be depressed. Then the apparatus is "under current".

1. Start.

To advance the carriage holding the airplane, depress button "Start". The motor will start up and the carriage will move by means of a screw shaft. The red light on the switchboard will light up.

2. Bomb release.

The bomb can duly be dropped from a moving airplane. When the estimated point of release has been reached, press the button marked "bombe fallt" (bomb falls). Through a magnetic clutch, a guide shaft is engaged which operates the guide threads. The bomb is held by two opposing threads, one attached to the tail, the other to the head of the bomb, and it is pulled down by the pulling thread, which is attached to the middle of the underside of the bomb. The increasing speed of falling of the bomb is created by spirals, on which the thread is rolled or unrolled, respectively. The sloping of the bomb from the horizontal into the vertical position is caused by the corresponding differences of speeds of the spirals of the bomb's head thread and tail thread. The change of tension of the pulling thread, which is caused by the different speeds, is equalized or regulated, respectively, by the tension spring, which lies above the carriage.

3. The time unit clock.

When pressing the button "bombefallt", a time unit clock is put into motion, and the red light on its face lights up. Through a toggle switch the bomb can be set for "without time unit" or "with time unit".

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Appendix II B (Cont'd).

(a) Without time unit.

By setting the bomb for "ohne Zeiteinheit" (without time unit), it will fall without interruption until it hits, whereby the clock's hand will make four revolutions. Upon the hit, the motor is switched off by a contact switch and the apparatus stops. The contact switches for the bomb are on the wheel housing.

(b) With time unit.

If the switch is on "mit Zeiteinheit" (with time unit), then the carriage and the bomb will stop after each completed revolution of the time unit dock, and the motor will be switched off. To continue, it will be necessary to switch to "Start". Since the motor stops after each revolution of the hand, this process repeats itself four times until the bomb arrives at its point of impact. The increasing speed of fall during these four periods can be graphically drawn in each time unit. The hand of the time unit clock can be set by a socket wrench on the backside of the clock.

4. Stop.

By pressing the switch "Halt", the apparatus can at all times be completely put out of operation. If this does not happen by using switch "Halt" or by a bomb hit, then the carriage continues on its course until at the end a contact stops the apparatus automatically.

5. Reversing the apparatus.

After the apparatus comes to a stop, the carriage can be brought to its initial position from any other one by pressing the switch "Ruckstellung", or an end contact will stop the apparatus automatically. To bring the bomb back to its starting position, when putting the apparatus into reverse, the switch "Bombe fallt" must also be switched on. The bomb will then be drawn up until it touches the airplane. The thread guides are stopped by a contact switch in the wheel housing and the bomb will come to rest on the airplane, although the carriage may continue to move. The contact switches for dropping the bomb (forward and reverse) must be adjusted very precisely through the door of the wheel housing.

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Appendix II B (Cont'd).

6. Sidewise movement for wind correction.

The drift caused by wind is indicated by a sidewise movement of the housing. By this movement the airplane will be pushed sidewise, as the carriage guides, and also the rods carrying the airplane are parallel with the central axis of the housing. The housing turns about a center point, which lies approximately at the end of the first third of the path of flight. From this center, the housing and therefore the path of flight, may be moved sidewise by  $15^\circ$  to the left or right. This is done by means of the hand wheel on the left of the switchboard. Sidewise angular motion can be read on the dial on the switch side of the plate.

7. Target carriage.

To indicate targets, which move sidewise, forward or backwards two arms have been attached in the center axis, of the base plate, with turning points in the first and second third of the axis, respectively. At the start, on each of these arms, which can be moved  $360^\circ$ , a sliding carriage is moved by means of rotating screws from the perimeter to the center. The carriage of arm No. 2 has a magnet upon which a target (a small iron automobile) may be placed. Since the arms can be set parallel in any position of the circle by means of a hand wheel, which is on the right of the switchboard, the target can be set in any direction, while the airplane is moving and independently from it. The angle can be read from a dial next to the hand wheel.

8. Trail.

Trail is indicated by means of a red thread. The thread is pulled by a self-tightening roller above the airplane and is hooked to the airplane's shadow, which is a few centimeters above the base plate, whereby the trail is clearly indicated by the bomb which hits about  $11.5^\circ$  to the rear.

9. The Angle Elevation.

This is indicated by a black thread, which is pulled by a self-tightening roller above the airplane and is hooked to the target on arm No. 2, which is held fast by a magnet.

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Appendix II B (Cont'd).

10. Measuring the angle of elevation.

The angle of elevation can be measured by a protractor arc, the adjustment of which for sidewise movement up to 15° left and right is done by a lever on the bomb support and can be read on a dial.

11. Map.

To indicate the steering of the airplane to counteract sidewise drift, a map is attached to the carriage of arms 1 and 2. When the arms, set parallel, move, the map may be moved in the same direction by the carriages, whereby the target is driven from or towards the direction of flight of the airplane. This drift can be corrected by the airplane by sidewise movement (see paragraph 6 above). For technical reasons, an illusion had to be simulated: In reality the earth is still and airplane is steered to the side against the wind. Here the earth (map) is moved against the path of the airplane, but with the direction of the target carriage.

12. Graphical Demonstration of Drift.

The drift can be shown graphically in degrees in the base plate (earth). For this purpose, tracing paper is attached by two clamp devices of the base plate.

13. Curve of fall of bomb.

This curve is shown on a shade, which is attached parallel to the direction of flight of the airplane and which, by means of a hand wheel to the right of the switchboard, can be rolled and unrolled. In addition, the trail distance and time of fall of the four time directions are indicated by coordinates. When the bomb is released at the beginning of the curve then the curve motion of the bomb will coincide with the curve on the shade, which can be clearly demonstrated.

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Appendix II B (Cont'd).

14. Speed regulator.

The speed of the motion of the carriage and the fall of the bomb is regulated by a potentiometer (wheel to the right under the wall of switchboard).

15. Adjusting of the bomb.

The bomb must be attached under the airplane in horizontal position and lightly against the springing guide socket. The fall must proceed from the horizontal into the vertical positions, until the bomb hits the target at an angle of about  $10^{\circ}$ - $15^{\circ}$ . First the horizontal position of the bomb on the airplane must be adjusted. This is done by means of two spirals on the carriage, whereby attention must be given to the ends of the left and right spiral which must coincide. A further fine adjustment can be made to the bomb itself, by loosening the thread tension screws at nose and tail of bomb by pulling or releasing the thread, and by tightening the screws. The start and finish of the fall is to be regulated by the contacts which are in the wheel housing. It is to be noted that the rough adjustment is done by means of the screws (on the adjusting ring, and the fine adjustment by means of adjusting screw) on the switch lever. The adjustment of the thread spirals on the wheel housing is done by the hand screw in the center, whereby the spiral must be turned in such a way that the bomb hangs under the plane in the desired position. Then the hand screw is tightened. Moreover, the thread may be tightened or loosened on the perimeter of the spiral by moving the screw at the place where the thread is attached.

16. Trouble shooting.

(a) The magnetic clutch may not operate properly. Adjust tension spring until the clutch upon being disconnected immediately stops the guide shaft.

(b) The relays do not react immediately. Clean for dust at places of contact.

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Appendix II B (Cont'd).

(c) The bomb guide threads have become loose. Tighten tension spring above the carriage. Oil all bearings, which are not ball bearings. Lubrication openings are marked red.

Henkel und Grosse, K.G.  
Pforzheim,  
Simmler St. 18

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APPENDIX II C

TRAINING APPARATUS FOR TROOPS FOR REMOTE CONTROLLED FALLING BOMBS

1. Purpose.

Bombardiers are to be instructed in the operation of remote controlled falling bombs, which can be steered by small surface vanes, whereby the force of gravity is partly transformed into deviation from the natural curve of fall. All observations by means of the bomb sight, its handling and the resulting hits are reproduced in the training apparatus true to reality.

2. Presentation.

The controlling of the bomb is done by means of an acceleration control system. Since the speed of the bomb and the steering pressure increase in time in the same proportion, the observed angle accelerations are independent of distance. The bomb is represented by a spot of light, the motion of which over ground coincides with the laws of fall and trim. This motion is furthermore influenced by the joy stick. The target is represented by a dot with two concentric circles for the measurement of hits. The dot moves towards the bombardier with the speed of the airplane, in addition to the motion of a ship. This motion can be set according to speed and direction so that evasive action can be represented, making practice more difficult. If the airplane changes course, the target will move sidewise in the same way it would appear to the bombardier in the plane. A training Loft is installed as bomb sight. The training altitude is 6000 meters. Speed 400-500 km/hr.

After each bombing run, all practice runs can be returned to their point of departure, so that when starting over again, all operations must be reinacted, which would be necessary in bombing. Any faulty operation will produce the same effects as in reality.

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APPENDIX II D

TRAINING APPARATUS FOR TROOPS FOR REMOTE CONTROLLED GLIDING BOMBS

1. Purpose.

This apparatus is for the training of operators of remote controlled bombs which glide because they have airfoils. It is here assumed that all appearing phenomena of the target as of bomb, which is represented by a dot of light, are reproduced true to nature. Moreover, in the manipulation of the remote control system type of motion and amount of force has been reproduced.

The control of the bomb is done by an acceleration steering system. It is a property common to all such systems, that steered values can only be recognized by the eye, when they have reached a certain degree beyond the increasing speed. Since beyond this the observed errors are "angle values" with increasing distance and correspond to larger absolute errors, and since the sensitivity of the eye decreases with the length of the time of observation, the bombardier must be instructed to bring the bomb into line with the target, first slowly and deliberately and keep it aligned until the hit occurs. Since the time of the hit depends principally upon the distance of the bombing, and since estimating the distance is impossible, the bombardier will become trained to an increasing degree of concentration.

2. Presentation.

The bomb is controlled by a joy stick which governs direction and amount of acceleration, independently of distance. The position of equilibrium on the training apparatus is reached corresponding to the bomb when the stick has been lifted  $15^{\circ}$  from the horizontal. So as to bring the bomb, which to begin with is invisible, into the field of vision of the bombardier and so as to aim it at the target, one should begin with a  $20^{\circ}$  turn of the stick to the right and to raise it until it goes no further.

The bomb is represented by a dot of light which decreases in size depending on distance. As it moves on a stationary wall, and therefore remains at the same distance from the bombardier, so the

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Appendix II D (Cont'd).

dependence of distance of the angle speed to time has been built into the gears.

To represent a target, a strip has been chosen, which passes in front of the bombardier with the speed of flight. Disturbances to observations while aiming, due to movements of the airplane (turbulence) are also represented and can be switched on, if desired. An even sequence of disturbances has been avoided, by corresponding technical means.

3. Note.

Advance exercises with the "Field Training Apparatus" (small ball apparatus) before the pupil is trained on the troop training apparatus, appear to be of use, because of the basic difficulties inherent in all acceleration control systems.

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APPENDIX III A

By  
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1. Introduction.

The testing of flak rockets of the most varied types is a protracted and expensive project. Often a great number of trial shots are necessary in order to find the proper values for the control elements or to uncover errors. At the same time consideration of the psychological setting (adjustment, alignment, etc.,) of the rocket control device and adaptability of the control to it is very desirable; likewise, a survey of the best military use and the probability of hitting the target (ratio of hits to misses) is desired.

These viewpoints led to the development for the purpose of experimental study of a model apparatus by means of which attempts are made to imitate or reconstruct as truly as possible the example (flight path) of the actual rocket course, and at the same time being able to investigate experimentally these courses in the laboratory.

For this purpose we have constructed an installation for cross winged rockets of the "Wasserfall" type, which installation or device is based on the following principles:

(a) The path of the bombers which are attacked by the rockets and the path of the rockets are reduced proportionately; i.e., in the ratio of 1:5000, so that the whole or total flight of the rockets to their target has ample space in a large experimental room. The time factor appears in true magnitude.

(b) In place of the actual rockets and bombers, two spheres of about 5-8 mm in diameter are used.

(c) These two spheres can move (or be moved) in the experimental room independently of one another in all three directions.

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Appendix III A (Cont'd).

(d) The bomber sphere and the rocket sphere are each controlled in their movements by a man, the controller with the result that both spheres execute movements just as they are actually executed by an aircraft and a rocket.

(e) It is the task of the rocket controller (steersman) to guide his sphere to the moving target on a three point path: eye, rocket, and target always in a straight line.

It is obvious that model apparatus of this type can also serve as an exact training and practise device for soldiers who are supposed to learn rocket controlling, although the apparatus probably costs too much (for this purpose) and simpler practise apparatus can be built.

We next built a simpler installation which gave little consideration to the exact aerodynamic conditions of the rocket and its control. This installation can be considered as a practise apparatus for soldiers. On the basis of our experiences with this apparatus (I) we designed an apparatus (II) which was to function much more accurately and was to give us quantitative results about the path, the angle of pitch, and many other factors.

The qualitative functioning apparatus (I) is completed, but is dismantled at the moment. The quantitative apparatus (II) is almost completely constructed. It is about 50 per cent constructed, but has not yet been tested. Apparatus (I) will be described first together with the principle common to both devices.

(a) Apparatus I.

In an experimental room there is a wooden frame of about 5 meters in length, 3 meters in width, and 3 meters in height. If one considers the scale ratio of 1:5000 this represents a flight range 25 km long, 15 km wide, and 15 km high. This frame carries two rails on which two carts travel. Figure 1 in the appendix shows schematically the frame with the two carts. Each of these carts can be moved independently. One carries the target, the bomber, in the form of a small sphere. The other cart carries the rocket sphere. The target cart can pass

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Appendix III A (Cont'd).

through below the rocket cart. Both carts move on the rails which form the Y-axis of the coordinate system on which the frame is based. The target cart carries a small cart with a windlass. This small cart moves itself on the large target cart in the direction of the X-axis of the coordinate system.

On the windlass there are several strands of wire to the ends of which the target sphere is attached. By winding the wire up or down the target sphere is moved in the direction of the Z-axis of the coordinate system. By simultaneous movement of the large and small carts as well as through winding of the wire, the target sphere can be moved on a very spacious trajectory.

The rocket cart is built in almost the same way. It also consists of a large cart which runs in the direction of the Y-axis and carries two small carts on vertical bars. These small carts are moved in the Z direction. One of the smaller carts is equipped with a windlass, from which a close wire pulley which carries the sphere representing the model rocket leads to the small cart lying opposite. By simultaneous moving of both the large and small carts as well as by turning the windlass, the model rocket is made to pass through a three dimensional trajectory.

The movements of all the carts and the winding of the windlasses are carried out partly electrically by synchronizing systems and partly mechanically by means of cables. The moving and winding speeds are determined by calculating machines which are set up near the frame.

This principle of construction is common to both apparatus I and II. Now only Apparatus I will be described further.

One hypothesis on which Apparatus I is based is that the speed of the rocket (through experiments) as well as the speed of the target (through an arbitrary assumption according to size) is known. Apparatus I was constructed so that various target speeds can be incorporated, while an average variation of rocket speed as a function of time was known from experiments.

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Appendix III A (Cont'd).

A second important hypothesis for Apparatus I is that the speed of the aircraft and rocket is governed by the two controllers directly by means of Knuppel. Both speeds are determined as vectors in the X-Y-Z coordinate system, according to size and direction. Figure 2 shows these vectors and the angles which the controllers govern with their mounted Knuppel. For Apparatus I we require not the resulting vectors, but rather their components in the directions of the axes for moving the carts and winding the windlasses. The components are given by the following expressions for the target:

$$V_x = V_F \cos y \sin$$

$$V_y = V_F \cos y \cos$$

$$V_z = V_F \sin y$$

When  $V_F$  means the speed we get the following target.

For the rocket we get the following expressions:

$$V_x = V_R \sin x$$

$$V_y = V_R \cos x \sin$$

$$V_z = V_R \cos x \cos$$

Where  $V_R$  represents the momentary speed of the rocket.

Thus we arrive at the following total requirements of calculating apparatuses and individual parts for Apparatus I:

- (1) One Knuppel each for aircraft and rocket.
- (2) Two calculating machines which reckon the expressions (1) and (2) including the time and altitude variations of  $V_F$  and  $V_R$ .
- (3) The frame with the carts, model target and model rocket.

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Appendix III A (Cont'd).

The transfer of the angle pairs  $y.a.$  and  $qx$  to the calculating machines is effected electrically. Then the value of  $V_x$ ,  $V_y$ , and  $V_z$ , which were calculated according to (1) and (2) are carried on further mechanically and electrically. This construction is presented schematically in Figure 2.

A third stipulation in the case of Apparatus I was made for the changing of the position of the speed vectors. If such a change of position is commanded by the controllers through the Knuppel, that is, if he wants to turn (literally - attain a curve in his line of flight) this command will not be carried out at once. Instead the old position of the speed vector changes with constant speed until it reaches the newly chosen position. The path of flight thus does not change irregularly, but changes over to the new direction in a regular curve. This is an attempt to reproduce the actual flight conditions in a simple way.

It is now necessary to say something about the details of the calculating machines, which undertake the separation of the speed vectors into their components according to (1) and (2). Both calculating mechanisms are constructed similarly so that the description of the calculating procedure for the components of the rocket speed suffices for full understanding.

Figure 3 depicts this mechanical-electrical apparatus. It consists essentially of a number of friction discs like those usually found in mechanical calculators. One friction disc (calotte) is driven with a constant speed by one motor. The friction roll (wheel) of this disc is guided by the speed program-disc and thus receives a number of turns which is proportional to the speed of  $V_R$ .

The friction roll drives two other friction discs, the rolls of which represent the values of  $\sin x$  and  $\cos x$ . The angle  $x$  is transmitted to the machine by the Knuppel and causes one motor to regulate itself with a fixed speed to this angle. This motor turns an axle on which a sine and a cosine program disc rest, which discs in turn guide the friction rolls. The number of turns of these rolls is thus proportional to  $V_R \cos x$  is multiplied by  $\sin Q$  and  $\cos Q$  in a similar manner to that just described and gives the components  $V_y$  and  $V_z$ .

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Appendix III A (Cont'd).

The wheels of the carts as well as the windlasses, are guided by these machine and to be sure the speeds  $V_x$ ,  $V_y$ , and  $V_z$ ; they cover, therefore, the distances  $S_x$ ,  $S_y$ , and  $S_z$ , which are the integrals of the speeds. The model rocket thus describes a path or trajectory which results from  $S_x$ ,  $S_y$  and  $S_z$ .

We summarize:

- (1) Apparatus I is an apparatus for qualitative presentation of guided flak rockets. It is complete, all parts available, but dismantled.
- (2) Apparatus I gives the trajectory of the rocket in the proportion of 1:5000. It presumes that the value of the speed of the target and rocket, as a program, is known; that the position of the speed vectors is determined by a target and rocket Knuppel respectively, directly through command controls of the two angles, and that the altering of the position of the vectors take place regularly.
- (3) Apparatus I gives little consideration to the flight mechanics of the rocket. It cannot be used for the control of the angle of pitch or of the guidance of the rocket.
- (4) Apparatus I can be utilized for fundamental experiments as well as for special practice for soldiers who have already had some training.
- (5) The total apparatus requirement comprises: two Knuppel, two calculating machines, two carts, one frame, and a control desk.

Figure four (4) shows a photographic view of Apparatus I. In the left foreground is the aircraft Knuppel by which the controller guides the aircraft cart. In the background to the right in a depression for the purpose of making the most efficient use of space, is the rocket Knuppel. The two carts can be seen on the rails of the frame. The cart further to the back with the vertical rods machines are housed in a wooden box. To the left and in front of them is the control desk.

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Appendix III A (Cont'd).

Apparatus II.

Apparatus II presents a materially amplified and refined design of Apparatus I. The previously described fundamental installations such as model frame, carts, for target trajectory presentation, and rocket trajectory presentation remain the same. Also, nothing fundamental was changed on the entire of the target trajectory path since with respect to the target it is only necessary to place very great demands on the rocket. The target thus doesn't need to be copied exactly from the point of view of control or aerodynamically; rather it must carry out merely movements similar to very fast maneuverable planes which can also dive steeply. Nevertheless, the imitation of the rocket trajectory was handled in a basically different way.

Apparatus II is the attempt to build an exact imitation of the flight trajectory of a guided flak rocket with the most far reaching consideration of its flight mechanism. It was built intentionally in a very loose and open way in order to be able to make changes and alterations easily; for example changes on the control equalization (guiding adjustment) etc.

In addition, apparatus II represents an attempt to determine the limits of model imitation, since one is forced comprehensively by the proportional reduction to inexactness and on the other hand cannot grasp all influences even with reasonable expenditure of apparatus. Next we discuss the theoretical principles of the apparatus.

The Theory of Apparatus II.

In reality the rudder machine of the flak rocket Wasserfall is given a command by the controller without benefit of wire. This command is answered by a resulting change in the rudder angle. Through this a disturbance of the balance moment arose and turning of the rocket in space followed. In connection with the turning around the center of gravity, there occurred simultaneously a change of the trajectory curve by reason of the air forces on the rocket and the changing over to a new direction. This process is to be imitated in Apparatus II.

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Appendix III A (Cont'd).

Let emphasis be made here on some qualities of the cross wing rocket, the "Wasserfall" which qualities are necessary to understand the apparatus.

(1) The cross wing rocket possesses two fixed stabilizing fins and pairs of rudders vertical to one another. A Knuppel control is associated unequivocally with each pair of rudders. A mixture of the controls does not take place.

(2) As a result of the built-in controls, the rocket can move in space in such a way as the surface normally can on a cardanic supported plate as in figure 5 by turning on the cardanic axis.

To imitate the actual process the relationships between the control on the Knuppel and the rudder angle (that is, the control equation) between the rudder angle and the turning of the rocket around its center of gravity, the moment equation, and between the turning on the center of gravity and changes of the trajectory curve, the trajectory equation, must be known.

We make use again of the designation system as shown in Figure 2. The control on the Knuppel we designate as  $\phi_K$  and  $X_K$ . The position of the rocket axis (lengthwise) is given through the angle  $\phi_A$  and  $X_A$  and the position of the trajectory tangents by  $\phi_B$  and  $X_B$ . Since the procedures and equations for both rudder axes of the rocket are almost identical, it is enough for the future to describe the imitation of one axis.

Next for the control equation. In the actual rocket there is a course gyro, the base of which is turned with a speed proportional to the control  $\phi_K$ . This gyro thus always measures the difference between the position of the rocket and the position of the base; that is, the value,  $Q_a - e \int \phi_K dt$ . This value from the gyro is transmitted to the rudder mechanism. At the same time the rudder mechanism receives a direct control connection  $e_0 \phi_K$  so that the following expression results for the rudder angle  $B_1$ :

$$B_1 = \lambda_0 \phi_A - e^{-1} \int \phi_K dt - e_0 \phi_K \quad (3)$$

The values  $\lambda_0$ ,  $e^{-1}$ ,  $e_0$  are chosen factors.

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Appendix III A (Cont'd).

The turning moment  $RB_1$ , caused by the rudder angle (with R as the specific rudder moment) ranges itself alongside the other moments which act on the rocket in the following equation for a stationary condition:

$$\Theta \dot{\phi}_A + D \phi_A + C(\phi_A - \phi_B) = \frac{RB_1}{\cos X_A}$$

In this equation  $\Theta$  is the inertia moment, D the damping coefficient, and C the specific moment of the force excited by the air. The factor  $1/\cos X_A$  appeared due to geometrical conditions.

The equation of the forces acting on the center of gravity ultimately reads:

$$\frac{VR}{G} \dot{\phi}_B = n^2 (\phi_A - \phi_B) - \frac{\sin \theta_B}{\cos X_B} \quad (5)$$

with  $n^2 = \left( \frac{P}{G} + \frac{dq}{dx} \right) \cdot \epsilon \cdot \frac{F}{G}$

in which VR is the rocket speed, P the thrust, G the weight, q the dynamic pressure, and F the groove surfaces.

These three equations make it possible for us, although they contain some negligible errors, to calculate the position of the rocket axis (lengthwise) in space as well as the position of the trajectory vectors. These calculations are made by machines whose construction and interaction is to be described in detail.

Construction of Apparatus II.

The shortness of time allocated for this report made it impossible to show all calculating mechanisms in schematic diagrams. Consequently, only the most important can be assembled. Detailed descriptions of Apparatus I and II are to be found in the indexed reports at the end.

Figure 6 shows the gear of Apparatus II for representation of the rocket trajectory. Starting from the Knuppel control, the rudder and moment equations are solved next by an electric mechanical calculating machine. Combining equations (3) and (4) above one gets the following expression, assuming that no consideration is given to the small amount of oscillation around the center gravity

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Appendix III A (Cont'd).

(that is if one makes the factors C and D equal to zero).

$$C(\phi_A - \phi_B) = \frac{R}{\cos X_A} (X_0 - e_{-1} \int \phi_K dt - e_0 \phi_K) \quad (6)$$

The neglected factors would not be absolutely necessary, but if desired, equipment could be constructed for these factors.

The simplified equation (6) contains the factors R, C, X, e-1 and e<sub>0</sub>, which are partly dependent on the time and the elevation. Tapered cams handle these values in the calculating machines automatically. They are returned according to the time and shifted according to the height.

Equation (6) is supposed to give the position of the rocket axis (lengthwise)  $\phi_A$ . It is not soluble alone since a coupling with the position of the trajectory path tangent takes place through the angle of pitch. Therefore, equation (5) must be solved simultaneously and the result used for solving equation (6).

In figure 6 thin lines show the course of the individual values between the different apparatuses. In addition the value of the course gyro  $\phi_A - e_1 \int \phi_K dt$  is also necessary. This gyro must be moved exactly as it is in the actual rocket. In order to make this possible such a gyro is placed on a cardric supported plate, which is constantly in a position in the room exactly like the position of the rocket. Then the measure value  $\phi_A - e_1 \int \phi_K dt$  can be determined from this gyro in order to use it for calculating the moment equation in accordance with (6). The following gear is required: One Knuppel one calculating machine for steering, and a moment equations, cardric supported plate with the course gyro, and a trajectory tangent calculator, which calculates the position and the speed on the basis on equation (5).

The apparatuses do not operate independently of one another but are coupled as shown by the equations. We want to describe the process which takes place in the calculating machine in the case of a control command  $\phi_K$ . In the calculating machine for the moment and

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Appendix III.A. (Cont'd).

steering equations the new rudder angle  $B_1$  is figured out according to equation (3) and used for calculating the balance moment according to equation (6). At the same time this control command  $\phi_k$  turns the base of the gyro on the cardanic supported platform which base continues to be turned by the continually recalculated value of  $\phi_A$  according to equation (6). By means of the new  $\phi_A$  values the trajectory tangent calculator is caused to produce further calculations and does its part for the pitch angle in the moment equation and at the same time gives the new position  $\phi_B$  of the vector  $V_R$ . This group of machines, consisting of a Knuppel, a calculating machine for equation (6), a cardanic supported plate, and trajectory calculator gives the following continued calculation.

(1) The position of the rocket axis in space through the angles  $\phi_A$  and  $X_A$  symbolically presented through the position of the cardanic plate.

(2) The position of the speed vector through the angles  $\phi_B$  and  $X_B$ .

From this position of the rocket axis and the speed vector and by using the more nearly correct relationship.

$$(\phi_A - \phi_B)^2 \cos^2 X_A + (X_A - X_B)^2 \quad (7)$$

in another calculator (the pitch angle calculator) the pitch angle  $\alpha$  can be determined.

The result of the trajectory path tangent calculator (the angles  $\phi_B$  and  $X_B$ ) is now conveyed to a calculating machine, which is constructed exactly like the one described for Apparatus I and sketched in Figure 3. It takes the speed of the rocket recorded on a tapered cam as a function of flight time and flight elevation, and breaks down the speed vector into three components according to equation (2). The speed components are transmitted electrically to the rocket cart and the latter moves accordingly.

Through the solution of equations (3), (5), (6) and (7) and by taking into consideration simultaneously the value occurring in the equations, which values are dependent upon time and elevation the flight

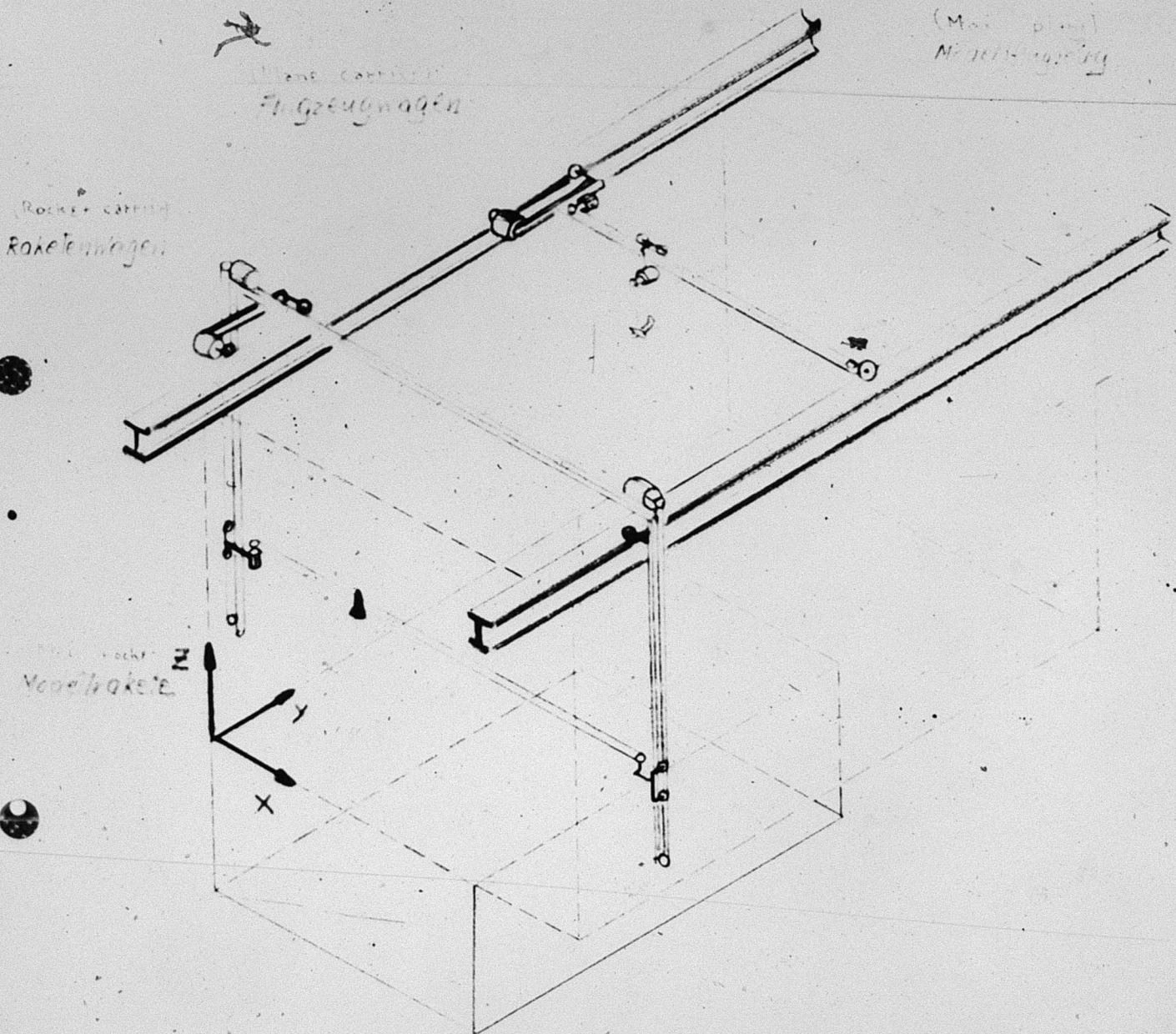
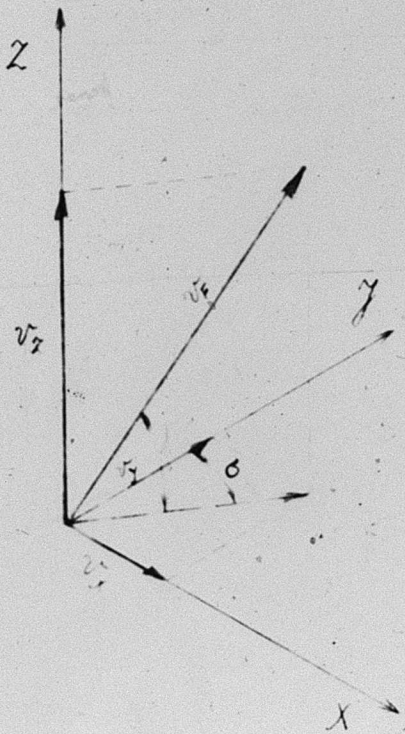
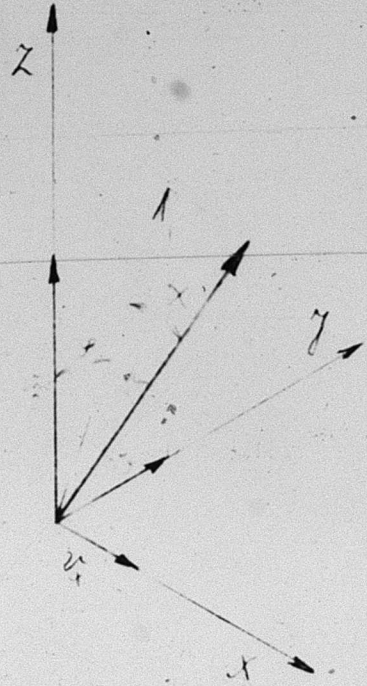


FIG. 1.  
 Bild 1



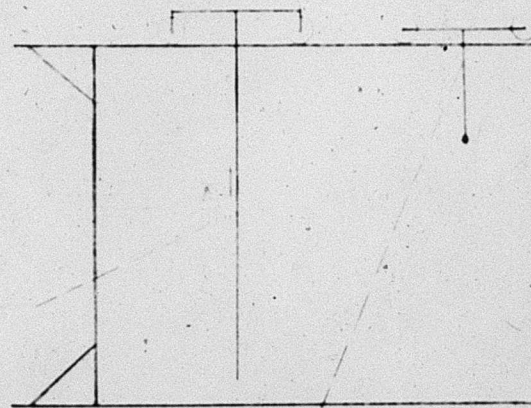
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Flugzeug



(Component resolution)  
Komponentenzerlegung

(Rocket)  
Rakete

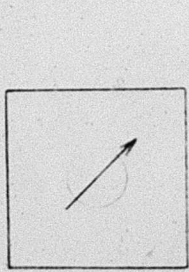
(Frame with carrier)  
Gerüst im Wagen



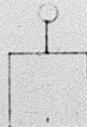
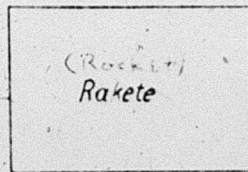
(Command disk)  
Kommandopult

(Stick)  
Knüppel

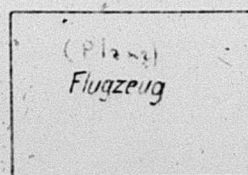
(Resolution machinery)  
Zerlegungsgetriebe



$\varphi, x$



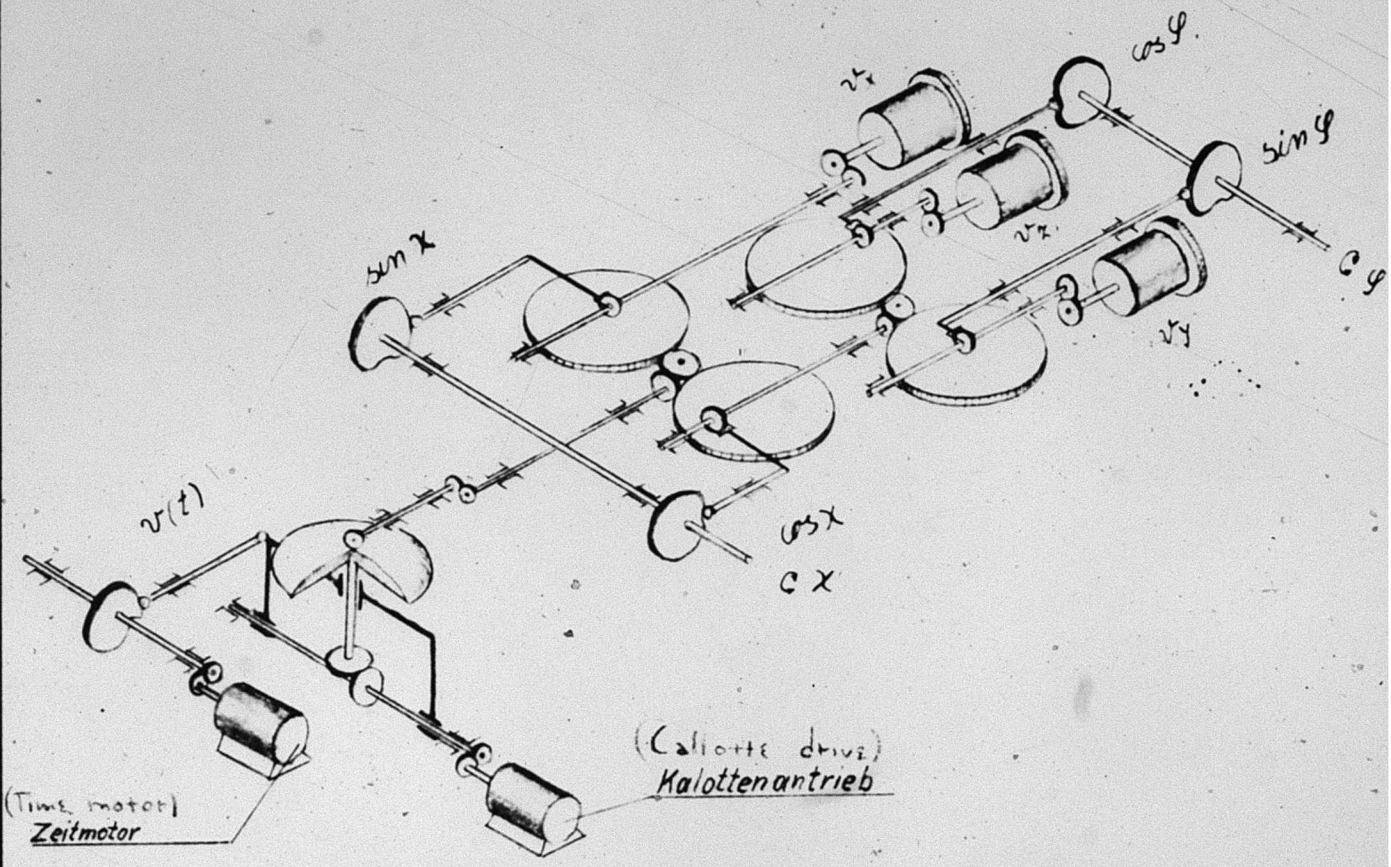
$\gamma, \sigma$



(Total consumption)  
Geräte-Gesamtaufwand

FIG. 2  
Bild 2



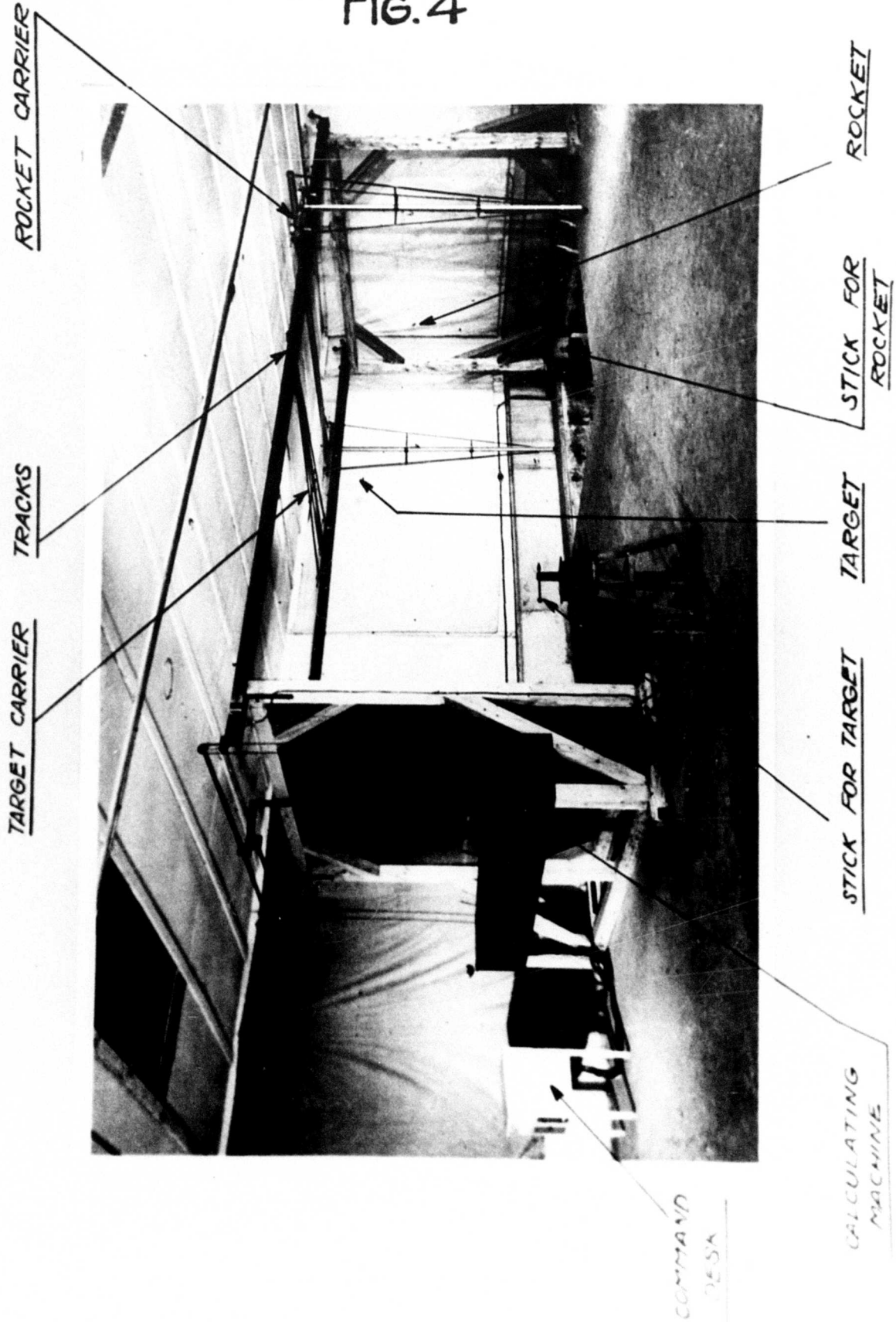


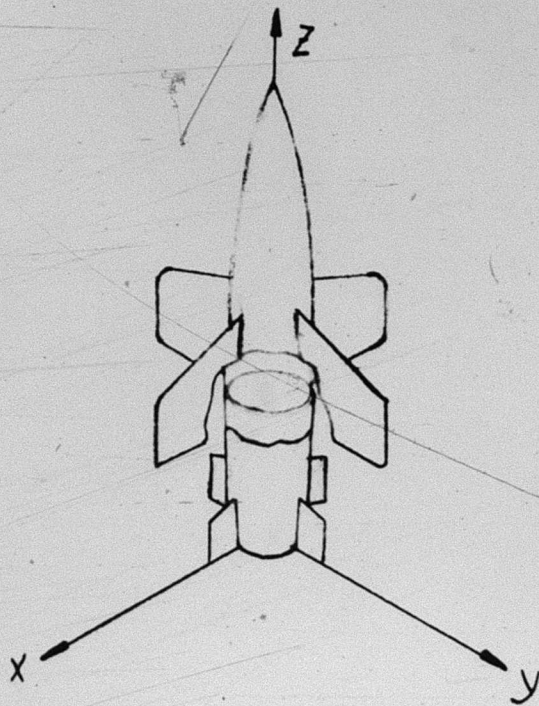
(Resolution machinery)  
Zerlegungsgetriebe

FIG.3  
 Bild 3

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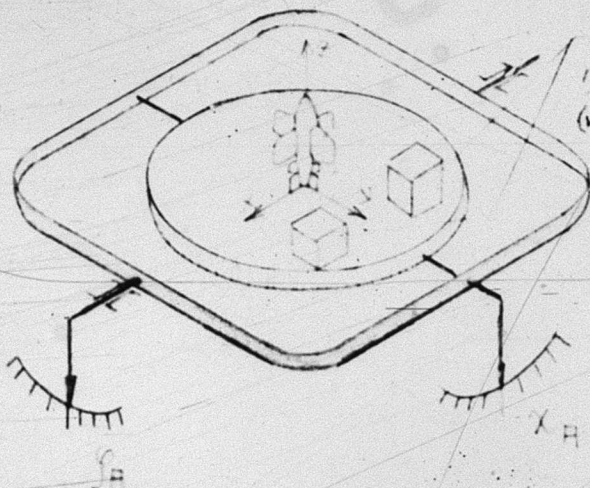
FIG. 4





(Phantom rocket)  
Flugobjekt

(Direction given)  
Richtgeber  
MESSER 40, 100 X 40  
(measure)



(Cardanic plate)  
Kardanisch gelagerte Platte

Bild 5.  
FIG. 5

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(3) Frame

(4) Center

(5) (Point - Point)

(6) (Point - Point)

(7) (Adjustment)

(8) (Component Solution)

FIG. 6

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Appendix III A (Cont'd).

the flight procedure of the rocket in Apparatus II is as correct, physically speaking, as possible, and actual conditions have been correspondingly well imitated. One can undertake changes in the apparatus ( for example, use other steering processes ) change the magnitudes of the influences, and supervise the results constantly, by recording the position of the rocket, the pitch angle and the trajectory. At the same time one can determine with this apparatus how suitable and satisfactory the steering mechanism is for the individual controlling the mechanism. Moreover, one can provide the finishing touches to the training of soldiers who have already had some training in guided missiles.

The presentation of the target trajectory is the same as in Apparatus I. For the complete installation a control desk is required, from which the apparatus is set in motion.

Since the flak rocket is to be guided even when visibility is poor or nil, several other apparatuses for guiding without sighting have been prepared. They determine by calculation the direction of the line of sight from the rocket emplacements to the target and the rocket and indicate to the rocket controller on a screen the angle of deviation of this line of sight.

Thus Apparatus II is described in general. It is mainly for the cross winged Wasserfall. Further designs and preliminary plans have been prepared for other flak rockets, for example for the single wing rocket.

A detailed description of Apparatus I and II are found in the reports of the Headquarters for Scientific Reports, ZWB, No. 3508 and 3558, both by J. Schedling.

Bad Reichenhall 5 July, 1945.

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APPENDIX III B

Interrogation of Dr. SCHEDLING and F. SCHLOGL, 17-18 June 1945 Bad Reichenhall.

Present: Carl H. SMITH, J. R. DeBAUN and P. W. WILKINSON.

Dr. SCHEDLING and F. SCHLOGL were working on the development of a model which would simulate the operation of the Flak rocket Wasserfall as accurately as possible. Actually the construction was such that any constants could be inserted and other Flak rockets investigated. The model was to be built on a scale of 1:5000 and the dimensions were such that the capabilities of the machine were extended to encompass ranges, altitudes and maneuverability of projectiles and targets which might be developed in the future. For example, the machine was to handle problems up to 40 km. in range and 25 km in altitude. The equipment was to be used for a multifold purpose to determine:

1. The minimum height of target wherein attack would be profitable.
2. Whether attack is more profitable against an approaching or receding target.
3. The aerodynamic coefficients of the projectile necessary for stability and sufficient maneuverability.
4. The psychology of the operator - in order to ascertain the most efficient controlling technique and to test controlling aides.
5. Whether two men instead of one should be used for the control - one for azimuth and one for elevation.
6. If the gyros in the projectile are able to operate in all positions.

An earlier model was completed in January 1944 which was capable of qualitative information only. Parts of this apparatus were seen at Teissendorf. The equipment had been dismantled for shipment to Henschel for training purposes and part shipment made. This equipment had proven of great value and the second equipment described herein, was designed to give as accurate quantitative information as possible. At the time of the occupation the project was approximately 50 per cent complete. A working model of the

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Appendix III B (Cont'd).

of the mechanical computer had been constructed and was seen at Teissendorf. They were still awaiting delivery of the electrical computer and did not know the state of progress. The frame with tracks, synchronizers and carts for the projectile was nearing completion. The frame, etc., for the target had not been started but design was complete. The control stick and computer for the target was to have been a duplication of previous work and so was merely a construction problem. Also at Teissendorf, in a nearby barracks building, was seen the intended site of the equipment. The concrete walls had been poured about two weeks before the occupation for a room large enough to house the equipment which occupied a space approximately 4 x 8 x 5 meters.

The equipment naturally divides itself into two parts, the target and the projectile. These will be described separately.

TARGET EQUIPMENT

In an effort to keep the target equipment as simple as possible and since the first equipment had produced an adequate solution it was decided to duplicate this equipment with an extension of range, altitude, speed, and maneuverability. The control stick position directly gives the trajectory direction at every instant of time. The control stick by means of pickoff potentiometer gives the elevation angle,  $\alpha$ , and the azimuth angle,  $B$ , referred to a right-handed system of cartesian coordinates as shown in Figure 1, where the x-y plane is the ground plane. Angle  $\alpha$  is referred to the x-y plane and angle  $B$  is referred to the y-z plane.

The electrical output of the control stick by means of a conventional bridge circuit drives a small DC motor to position a shaft in the mechanical computer input to represent the angle  $\alpha$ . A similar arrangement positions a shaft to represent the angle  $B$ . A functional sketch of the mechanical computer is shown in Figure 2. The function of this computer is twofold. The speed of the target plane is dependent upon the height,  $H$ , and the angle  $\alpha$  in addition to its inherent speed and maneuverability. The first function of the computer is to give the absolute magnitude of the velocity as a function of  $H$  and  $\alpha$ . The angles  $\alpha$  and  $B$  are given by the control

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Appendix III B (Cont'd).

stick. The second function of this computer is to convert  $v$  and  $B$  to the cartesian components of velocity,  $V_x$ ,  $V_y$  and  $V_z$  to operate the travelling carts on the frame and thus fix the target position at each instant of time.

The velocity of the target is compensated for altitude,  $H$ , and elevation angle,  $\alpha$ , by means of a three-dimensional cam as shown in the figure. The cam is rotated to correspond to angle  $\alpha$  by the DC motor and shifted along its axis to correspond to  $H$ .  $H$  is actually obtained by integrating the component  $V_z$  with respect to time and transforming this to axial motion of the cam. A follower on the cam is used to displace a hemispherical integrator driven at constant speed.  $|v| = f(H)$  is now available at the integrator output as a variable shaft speed and is used to drive a pair of disk integrators as shown also in Figure 2.  $\sin \alpha$  and  $\cos \alpha$  are obtained by means of cams, the translational motion of the follower giving the sine or cosine of the angular position of the cam determined by  $\alpha$ . We now have at the output of one integrator the component  $|v| \sin \alpha$  or  $V_z$ . The output of the other integrator gives  $|v| \cos \alpha$  which is used to drive a similar second pair of integrators. Another pair of cams give  $\sin B$  and  $\cos B$  from their followers as determined by the angular position of their shafts driven by input  $B$ . The translational motion of the followers are fed to the second pair of integrators and thus give at the integrator outputs  $|v| \cos \alpha \sin B$  or  $V_x$  and  $|v| \cos \alpha \cos B$ , or  $V_y$ .

The component velocities  $V_x$ ,  $V_y$ , and  $V_z$  are picked off by Synchro generators and used to drive Synchro motors to move the carts on the frame. A functional sketch of this target frame is given in Figure 3.

The synchros drive the carts direct for motion along the  $x$  and  $y$  axes while a synchro drives a reel to give the  $z$  axis motion of the target which is suspended by a wire wound on the reel.

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Appendix III B (Cont'd).

PROJECTILE EQUIPMENT

This equipment was considerably more intricate since it was the intention to exactly duplicate the rocket action. In order to accomplish this it was decided to mount a platform in gimbals so that freedom of motion in two dimensions was provided. The axis of the projectile can then be represented by the perpendicular to the platform and gyros affixed to the platform that exactly duplicate the action of gyros in the projectile. In order to insure that the gyros operate properly the coordinates are taken somewhat differently than for the target. The angles of the command  $P_k$  and  $V_k$  are taken with reference to the right handed system of cartesian coordinate axes as shown in Figure 4, where, as before, the plane X-y is the ground plane. Angle  $P_k$  is taken with respect to the X-Z plane and angle  $V_k$  is taken with respect to the Y-Z plane. The construction of the control stick is also somewhat different and is shown schematically in figure 4.

The problem consists of four primary parts:

1. The command.
2. The position of the rocket axis in space.
3. The direction of motion of the c.g. of the rocket in space or trajectory, and
4. Conversion of velocity to cartesian coordinates to drive the carts on the frame. The angle describing direction for 1, 2 and 3 are all taken in the same manner as shown for the Command in Figure 4. The following notations will be adhered to:

$P_k$	, $V_k$	Command
$P_A$	, $V_A$	Rocket Position
$P_B$	, $V_B$	Trajectory position
$\alpha$		Rudder angle

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Appendix III B (Cont'd).

Figure 5 is a schematic drawing of the computer.

The series of equations to be solved by the computer are the following:

The command from box 1,

$$P_K \quad \psi_K$$

is inserted in the rudder equation represented by box 2.

$$\left. \begin{aligned} \eta &= a \dot{P}_K + b \dot{\psi}_K + c \ddot{P}_K + d \ddot{\psi}_K + e \ddot{P}_A + f \ddot{\psi}_A + g \ddot{P}_A''' \\ \xi &= a \psi_K + b \psi_K + c \psi_K + d \psi_A + e \psi_A + f \psi_A + g \psi_A''' \end{aligned} \right\} (A)$$

represent gyro position as contrasted to rocket position given by  $P_A, \psi_A$ .

The rudder angles are then inserted in the set of equations:

$$\left. \begin{aligned} \Theta \ddot{\psi}_A + D \dot{\psi}_A + R \eta &= 0 \\ \Theta \ddot{P}_A + D \dot{P}_A + R \xi &= 0 \end{aligned} \right\} (B)$$

where  $\Theta$  = inertia movement  
D = damping  
R = rudder movement

And the solution  $\dot{P}_A, \dot{\psi}_A$  is used to drive DC motorsto position the gimbals driving the platform as shown at 4 in the drawing.

Since  $\ddot{P}_A, \ddot{\psi}_A$  are required in equations A, pickoffs on the gyros mounted on the platform furnish this information back to box 2.

The computation of equations A and B are accomplished electrically and since the work was done outside the DFS and not yet completed it was not possible to obtain further detailed information on this phase of the equipment.

The rocket position, represented by the platform, is picked off by synchro as shown at 4 and transferred to box 5, a mechanical computer for solving the additional equation:

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$$A \sin \theta_B + C \cos \theta_B = G \sin \theta_A + C \cos \theta_A$$

$$A \sin \psi_B + C \cos \psi_B = G \sin \psi_A + C \cos \psi_A$$

Equation C takes into account the angle of attack  $\alpha$  given in the equations by  $\theta_A - \theta_B$  and  $\psi_A - \psi_B$ , the component of weight, G, given approximately by  $G \sin \theta_A$  and  $G \sin \psi_A \cos \theta_A$  and the aerodynamic coefficients. The weight G, is a function of time since fuel is constantly used up and the aerodynamic coefficients are a function of altitude and time. From equation C are obtained  $\theta_B$  and  $\psi_B$  which represent the direction of the trajectory in space. This is converted to cartesian coordinate components of velocity  $V_x, V_y + V_z$  by a computer, box 5, similar in construction to that shown in Figure 2, with H and T as inputs instead of H and  $\theta_B$  and  $\psi_B$  as inputs instead of  $\alpha$  and B. Figure 7, to be described later is a functional diagram of this computer.  $V_x, V_y + V_z$  are then used to drive the carts on the projectile frame in a manner similar to the target frame. The mechanical computer of box 5 used to solve the equations C is shown in Figure 6. Three dimensional cams give the coefficient as shown in the figure, modifying them for time and altitude. The computer seeks the solution  $G \sin \theta_A + C \cos \theta_A = A \sin \theta_B + C \cos \theta_B$  and the output  $\theta_B$  is available at the point shown. A similar computer is provided for  $\psi_B$ . The information  $\theta_B$  and  $\psi_B$ , the direction of the trajectory in space, is given to the mechanical computer box 6, which is shown in Figure 7. The operation is similar to Figure 2 and will not be described in detail. It may be noted that H is given by  $\int V_z dt$  to provide altitude compensation input where shown on the figures. Time to input is provided by a constant speed motor. The output of box 6 is therefore the components of velocity  $V_x, V_y + V_z$  referred to cartesian coordinates. This output is picked off the mechanical computer by synchro generators and synchro motors on the frame operate the carts in a maneuver similar to the target frame. The construction of the projectile frame is somewhat different as may be noted in Figure 8. Instead of the Z component of velocity provided by a reel suspending a cable from the top cross member, two vertical tracks rigidly affixed to the component carts are used as shown in the sketch. The X component of velocity is then provided by a synchro driving an endless cable suspended between  $V_z$  carts on the vertical members.

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Appendix III B (Cont'd).

This equipment when completed should have been invaluable in studying the flakrocket problem from all six standpoints indicated in the early paragraphs of this report. If possible, it is recommended that the project be completed and taken to the United States for study of ground-to-air missiles. As noted in a previous report on Dr. FISCHER, the leader of the Institute for Aeronautical Equipment of DFS, where this work was undertaken, completion was estimated by Dr. FISCHER in six months time if continued at the same rate of progress and with the same manpower as at the time of the occupation.

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APPENDIX IV

PERSONAL HISTORY  
of  
DR. JOHANN SCHEDLING, Physicist

Education: 1926-1934: Bundesrealgymnasium (High School) Vienna 20.

1934-1938: Technical University of Vienna, Vienna  
Institute Field - Physics, Mathematics  
Doctoral work - Electron size and charge.

30 November 1938: Ph. D; Grade: good.

Professional Career:

1 January 1939 - 30 October 1941 - Laboratory engineer at  
AEG, Berlin. Work concerning electro acoustics, particu-  
larly regarding supersonic in water.

1 November 1941 - 30 June 1945 - Scientific Callaborator  
in Deutsche Forschungsanstalt fur Segelflug-Ainring (DFS);  
(German Research Institute for Gliders).

Works: Theory of Torpedo Course, gyro-stabilized  
telescope model apparatuses; study apparatuses;  
for copying of flight courses of guided missiles;  
calculating apparatuses.

Political Party:

German Worker's Front (DAF) to 30 October 1941. NSV.

For 3 months, drafted to SA Defense Corps.

Reichenhall, 1 July 1945.